A GUIDE BOOK
TO THE
LOCAL MARINE BOARD EXAMINATION.

ORDINARY EXAMINATION

BY T. L. AINSLEY.

6/-

A

GUIDE BOOK

TO THE

LOCAL MARINE BOARD

EXAMINATION.

THE ORDINARY EXAMINATION.

BY THOMAS L. AINSLEY,

TEACHER OF NAVIGATION.

NINTH EDITION.

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PREFACE TO THE FIRST EDITION.

THIS Work is intended as a Guide to the Officers of all grades of the Merchant Service, in the examinations they are required to undergo before the Local Marine Board. It will be issued in Two parts:—Part I containing what is termed the Ordinary Examination, and Part II containing the Extra Examination.

The present volume, which relates to the Ordinary Examination, contains model solutions of examples in the various problems required of Candidates when under Examination, with numerous Exercises to each problem, together with a variety of Examination Papers. It also contains all requisite information respecting the Deviation of the Compass; Lights of the English, St. George's, and Bristol Channels, &c.; Stowage of Cargoes; Invoices; Charter Party; Bottomry Bonds, &c.

In the preparation of the articles on Seamanship, the following works have been consulted:—"The Kedge Anchor," by W. Brady, U.S.N.; "The Seaman's Friend," by R. H. Dana, jun.; "The Sheet Anchor," by Darcy Lever, Esq.; while my obligations to other works have been duly acknowledged. The works of ABBOTT, LEES, STEELE, and M'CULLOCH, &c., are the authorities that have been consulted on the subjects of Charter Party, Bills of Lading, &c., &c.

South Shields, July 10th, 1856.

ADVERTISEMENT

TO

THE EIGHTH EDITION.

THIS Edition of the "Guide Book" has been very materially increased in size, principally by the insertion of such explanatory matter as seemed necessary to a clearer exposition of the various subjects contained in the work. The Answers to all the examples for exercises have been removed and placed at the end of the book, which arrangement it is believed will be found better than that of appending them to the questions themselves. The work has been carefully revised throughout, and will, it is hoped, be found still more useful to persons qualifying for Examination. Part II, containing the Extra Examination, is now in the Press, and will shortly be issued.

T. L. A.

South Shields, May 14th, 1864.

ERRATA ET CORRIGENDA.

Page 6, line 13 from top, supply "he must be able to find the bearing and distance of the port bound to, by Mercator's Method."

" 30, Ex. 13, index of log. of product should be 6.

" 32, Ex. 7, for ·003010, read ·03010.

" 39, line 11 from bottom, for "to find the log. sine of 120° 24'," read 110° 24'.

" 65, Ex. 2, for S.W. ¾ W., read S.E. ¾ E.

" 176, for magnetic azimuth S. 92° 30′ 0″ E., read N. 92° 30′ 0″ E.

" 184, Latitude by Raper mark S. instead of N.

" 189, Ex. 4, mark observed altitude N. instead of S.

" 226, Ex. 5, for Ushant, read La Heve.

" 277, *Ushant*, for N.E. point of Island, read S.W. The light on N.E. end is a fixed light as before.

" 316, Ex. 2, division by logarithms, for 96·14, read 96·16.

" " Ex. 8, " " for 14·66, read 12·35.

" 324, Ex. 3, for 1^h 49^m P.M., read 1^h 47^m P.M.

" 324, Ex. 13, the A.M. tide should be 11^h 25^m, and the P.M. tide 11^h 50^m.

" 327, Ex. 5, bottom line, log. of diff. long. should be 2·232899, and diff. long. 171·0.

" 47, line 7 from bottom of page, for 50°, read 45°.

" 66, Ex. 17, for off S.W. by W., read off S.W. by S.

" 79, first line from bottom, for 22·6, read 226.

" 121, Ex. 2, the red. decl. should be 20° 7′ 31″ N.

" 141, Ex. 18, for long 12° 52′ W., read 40° 43′ W.

" 145, line 6 from top, on the right hand, for 8th, 13^h 33^m, read 8th, 13^h 11^m.

" 159, Ex. 6, for decl. 23° 1′ 55″ N., read 23° 1′ 55″ S.

" 206, for 999·43, read 99943.

" 318, mid. lat., Ex. 3, for 1° 20½, read 2·10½.

" 318, long. in, Ex. 12, the correct answer is 92° 9′ E.

" 322, first line from bottom, Ex. 11, for 14° 17′ 14″, read 14° 16′ 59″.

" 331, Paper VIII, No. 3, for dist. 35·4, read 43.

" 332, first line for Aug. 19^d 20^h 37^m 39^s, read 19^d 20^h 37^m 41^s.

" 332, Ex. 11, mark decl. N. instead of S.

" 334, Paper XII, Ex. 3, lat. in should be 49° 35′·5 N., diff. long. 13′, and long. in 40° 13′ W.

" 334, Paper XII, Ex. 10, for variation 6° 18′ 29″ E., read 7° 18′ 29″ E.

" 334, Paper XIII, the answer given is that for another question. Substitute the following: Green. date 17^d 21^h 21^m 54^s; red. decl. 10° 53′ 29″ N.; true alt. 38° 22′ 36″; red. eq. time sub. 0^m 43^s; hour angle 2^h 40^m 36^s; long. 0° 48′ 15″ W.

" *336, Ex. 7, for* 9^h 3^m *P.M.,* read 9^h 30^m P.M.

" *337, English and Bristol Channels*, Ex. 10, for dist. 16, read 21.

CONTENTS.

NOTICE OF EXAMINATIONS

OF

MASTERS & MATES OF FOREIGN-GOING SHIPS

AND OF

HOME TRADE PASSENGER SHIPS,

Established in pursuance of the Mercantile Shipping Act, 1854;

AND OF

VOLUNTARY EXAMINATIONS IN STEAM.

UNDER the provisions of the Merchant Shipping Act, 1854, (17 and 18 Vict., c. 104, ss. 136—161,) no Foreign-going Ship* or Home Trade Passenger Ship† can obtain a clearance or transire, or legally proceed to sea, from any port in the United Kingdom, unless the Master thereof, and in the case of a Foreign-going Ship, the First and Second Mates or Only Mate (as the case may be), and in the case of a Home Trade Passenger Ship, the First or Only Mate (as the case may be), have obtained and possess VALID CERTIFICATES, either of COMPETENCY or SERVICE, appropriate to their several stations in such ship, or of a higher grade; and no such ship, if of *one hundred tons burden, or upwards*, can legally proceed to sea unless at least *one Officer besides the Master* has obtained and possesses a *valid* Certificate, appropriate to the grade of Only Mate therein, or to a higher grade; and every person who,

* By a Foreign-going Ship is meant one which is bound to some place out of the United Kingdom, beyond the limits included between the river Elbe and the harbour of Brest.

† By a Home Trade Passenger Ship is meant any Home Trade Ship employed in carrying passengers; and it is to be observed that *Foreign Steam Ships, when employed in carrying Passengers between places in the United Kingdom*, are subject to all the provisions of the Act, as regards Certificates of Masters and Mates, to which British Steam Ships are subject (s. 291).

B

having been engaged to serve as Master, or as First, or Second, or Only Mate of any Foreign-going Ship, or as Master, or First or Only Mate of a Home Trade Passenger Ship, goes to sea as such Master or Mate, without being at the time entitled to and possessed of such Certificate as the Act requires, or who employs any person as Master, or First, or Second, or Only Mate of any Foreign-going Ship, or as Master, or First, or Only Mate of any Home Trade Passenger Ship, without ascertaining that he is at the time entitled to and possessed of such Certificate, *for each offence incurs a penalty not exceeding Fifty Pounds.*

Every Certificate of Competency for a Foreign-going Ship is to be deemed to be of a higher grade than the corresponding Certificate for a Home Trade Passenger Ship, and entitles the lawful holder to go to sea in the corresponding grade in such last-mentioned ship: but *no Certificate for a Home Trade Passenger Ship entitles the holder to go to sea as Master or Mate of a Foreign-going Ship.*

A Certificate of *Service* entitles an Officer, who has already served as either Master or Mate in a British Foreign-going Ship before the 1st January, 1851, or as Master or Mate in a Home Trade Passenger Ship before the 1st January, 1854, to serve in those capacities again; and it also entitles an Officer who has attained, or attains the rank of Lieutenant, Master, passed Mate or Second Master, or any higher rank in the Service of Her Majesty, or of the East India Company, to serve as Master of a British Merchant Ship, and may be had by application to the Registrar-General of Seamen, Adelaide Place, London, or to any Shipping Master in the Out-Ports, on the transmission and *verification of the necessary Certificates and Testimonials.*

Certificates of *Competency* will be granted to those persons who pass the requisite Examinations, and otherwise comply with the requisite conditions. For this purpose Examiners have been appointed under the Local Marine Boards, and arrangements have been made for holding the examinations at the under-mentioned ports, upon the days specified against them; and these days are so arranged for general convenience, that a candidate wishing to proceed to sea, and missing the day at his own port, may proceed to another port where an examination is coming forward.

The days for commencing the Examinations at the various Ports are as follow:—

PLACES.	DAYS.
**Aberdeen*	On the first and third Friday and Saturday in each month; and additional Examinations when circumstances require.
Belfast	First and third Tuesday in each month.
**Bristol*	First and third Tuesday in each month.
Cork	Second and fourth Monday in each month.
Dublin	First and third Tuesday in each month.
**Dundee*	Saturday in each week.
**Glasgow* .... **Greenock*	Thursday and Friday in each week, held alternately at each place.
**Hull*	Second and fourth Tuesday in each month.
**Leith*	Second and fourth Tuesday in each month.
**Liverpool*	Monday, Tuesday, Thursday, and Friday in each week.
**London*	Examinations in Navigation commence every Monday at 10 A.M., and the Examinations in Seamanship as soon after as the Candidates may have finished their Navigation. All applications for Examination must be made on Friday from 10 till 4, and on Saturday from 10 till 2. The Examination of Master or Mate in Steam will be held on Friday in each week, and any application can be received before that day.
**Newcastle*	First day in each month not being Sunday.
**Plymouth*	First and third Wednesday in each month.
**Shields*	Eleventh and twenty-sixth of each month not being Sunday, from October to May. Eleventh day only in June, July, August, and September.
**Sunderland* ..	Sixth and twenty-first of each month not being Sunday, from October to May. In June, July, August, and September, on the twenty-first day only.

GENERAL RULES AS TO THE EXAMINATIONS.

Applicants for Examination must give their names to the Shipping Master, or to the Local Marine Board at the place where they intend to

* At these places Extra Examinations are held.

be examined, on or before the day of examination, and must conform to any regulations in this respect which may be laid down by the Local Marine Board; and if this be not done, delay may be occasioned.

Testimonials as to Character, Sobriety, Experience, Ability, and Good Conduct on board ship, will be required of all applicants, and without producing them no person will be examined. As such testimonials may have to be forwarded to the office of the Registrar-General of Seamen in London, for verification, before any Certificates can be granted, it is desirable that Candidates should lodge them as early as possible. Testimonials of servitude on board Foreign Vessels, before being received by the Examiners, are to be confirmed either by the endorsement of the Consul of the Country to which the Ship belongs, or by some other recognized Official Authority of that Country, or by the Testimony of some credible person on the spot having personal knowledge of the facts required to be established. Upon application to the Shipping Master, Candidates will be supplied with a form, which they will be required to fill up and lodge with their Testimonials, in the hands of the Examiners.

The examinations will commence early in the forenoon on the days specified for each place, and will be continued from day to day until all the Candidates whose names appear upon the Shipping Master's list on the day of examination are examined.

The Candidates will be allowed to work out the various problems in Navigation according to the Method and the Tables they have been accustomed to use, and will be allowed five hours to perform the work, at the expiration of which, if they have not finished, they will be declared to have failed, unless the Local Marine Board see fit to extend the time.

FEES TO BE PAID BY APPLICANTS FOR EXAMINATION.

The Fee for Examination must be paid to the Shipping Master. If a Candidate fail in his examination, half the fee he has paid will be returned to him by the Shipping Master, on his producing a document which will be given him by the Examiner.

The fees are as follow:—

For Foreign-going Ships.

Second Mate	£1	0	0
First and Only Mate, if previously possessing an Inferior Certificate	0	10	0
If not	1	0	0
Master, whether Extra or Ordinary	2	0	0

For Home Trade Passenger Ships.

Mate	£0	10	0
Master	1	0	0

Any one who has been one year in possession of a Master's First-class Certificate, granted by one of the former Boards of Examiners, or of an Ordinary Master's Certificate of Competency, granted under the present Examiners, may pass an Extra Examination, and receive an Extra Certificate in exchange for his former one, without payment of any fee; but if he fails in his first Examination, he must pay half a Master's fee on his coming a second time; and the same sum for every subsequent attempt.

If an applicant passes, he will receive a document from the Examiner, which will entitle him to receive his Certificate of Competency from the Shipping Master at the port to which he has directed it to be forwarded. If his testimonials have been sent to the Registrar to be verified, they will be returned with his Certificate.

If an applicant is Examined for a higher rank, and fails, but passes an Examination of a lower grade, he may receive a Certificate accordingly; but no part of the fee will be returned.

In all cases of complete failure, the Candidate must be Examined *de novo;* and in case of failure in *Seamanship*, a Candidate will not be re-examined *until after a lapse of six months*, to give him time to gain experience.

As the Examinations of Masters and Mates are made compulsory, the qualifications have been kept as low as possible; but it must be distinctly understood, that it is the intention of the Board of Trade to raise the standard from time to time, whenever, as will no doubt be the case, the general attainments of Officers in the Merchant Service shall render it possible to do so without inconvenience; and Officers are strongly urged to employ their leisure hours, when in port, in the acquirement of the knowledge necessary to enable them to pass their

Examinations; and Masters will do well to permit Apprentices and *junior* Officers to attend Schools of Instruction, and to afford them as much time for this purpose as possible.

QUALIFICATIONS FOR CERTIFICATES OF COMPETENCY FOR A FOREIGN-GOING SHIP.

A SECOND MATE must be *seventeen* years of age, and must have been *four* years at sea.

In Navigation.—He must write a legible hand, and understand the first four rules of Arithmetic, and the use of Logarithms. He must be able to work a Day's Work complete, viz.,—to correct the Courses steered, for Variation and Leeway; to find the Course and Distance made good, and the Latitude in and Longitude in by the Dead Reckoning; also to find the difference of Longitude by Parallel Sailing. He must be able to correct the Sun's Declination for Longitude, and find his Latitude by Meridian Altitude of the Sun; and work such other easy problems of a like nature as may be put to him. He must understand the use of the Sextant, and be able to observe with it, and read off the arc.

In Seamanship.—He must give satisfactory answers as to the rigging and unrigging of ships, stowing of holds, &c.; must understand the measurement of the log line, glass, and lead line; be conversant with the rule of the road, as regards both steamers and sailing vessels, and the lights carried by them.

An ONLY MATE must be *nineteen* years of age, and have been *five* years at sea.

In Navigation.—In addition to the qualifications required for a Second Mate, an Only Mate must be able to find the Bearing and Distance of the port he is bound to, by Mercator's Method: he must be able to observe and calculate the Amplitude of the Sun, and deduce the Variation of the Compass therefrom: and also be able to find the Longitude by Chronometer by the usual methods, from an observation of the Sun. He must know how to lay off the Place of the Ship on the Chart, both by Bearings of known objects, and by Latitude and Longitude. He must be able to use a Sextant and determine its error, and adjust it; and find the Time of High Water from the known time at Full and Change.

In Seamanship.—In addition to what is required by a Second Mate, he must know how to moor and unmoor, and to keep a clear anchor; to carry out an anchor; to stow a hold; and to make the requisite entries in the ship's log.

A FIRST MATE must be *nineteen* years of age, and have served *five* years at sea, of which one year must have been as either Second or Only Mate, or as both*

In Navigation.—In addition to the qualifications required for an Only Mate, a First Mate must be able to observe Azimuths and compute the Variation; to compare Chronometers and keep their Rates; to find the Latitude by single Altitude of the Sun *off* the Meridian; and be able to use and adjust the Sextant by the Sun.

In Seamanship—In addition to the qualifications required for an Only Mate, a more extensive knowledge of seamanship will be required, as to shifting large spars and sails, managing a ship in stormy weather, taking in and making sail, shifting yards and masts, &c., and getting cargo in and out; getting heavy spars and weights, anchors, &c., in and out; casting ship on a lee shore: and securing the mast in the event of accident to the bowsprit.

A MASTER must be *twenty-one* years of age, and have been *six* years at sea, of which one year must have been as First or Only Mate, and one year as Second Mate, or two years as First and Only Mate.

In addition to the qualifications for a First Mate, he must be able to find the Latitude by the Meridian Altitude of a Star, &c. He will be examined in so much of the Laws of the Tides as is necessary to enable him to shape a course and to compare his soundings with the depth marked on the Charts. He will be inquired of as to the nature of the Attraction of the ship's iron upon the compass, and as to the method of determining it. He must possess a sufficient knowledge of what he is required to do by law, as to entry and discharge, and the management of his crew; and as to penalties and entries to be made in the Official Log. He will be questioned as to his knowledge of invoices, charter-party, Lloyd's agent, and as to the nature of bottomry; and he must be acquainted with the leading Lights of the Channel he has been accustomed to navigate, or which he is going to use.

* Service in a superior capacity is in all cases to be equivalent to service in an inferior capacity.

In cases where an applicant for a Certificate as Master Ordinary has only served in a fore-and-aft rigged vessel, and is ignorant of the management of a square rigged vessel, he may obtain a Certificate on which the words "*fore-and-aft rigged vessel,*" will be written. This is not however, to apply to Mates, who being younger men, are expected for the future to learn their business completely.

An EXTRA MASTER'S EXAMINATION is intended for such persons as wish to prove their superior qualifications, and are desirous of obtaining command of ships and steamers of the first class. Before being examined for an Extra Master's Certificate, an applicant must have served one year either as a Master with an *Ordinary Certificate of Competency*, or as a Master having a *First Class Certificate*, granted by one the former Boards of Examiners.

In Navigation.—As the vessels which such Masters will command frequently make long voyages, to the East Indies, Pacific, &c., the candidate will, in the first place, have to make all the Computations required of Master Ordinary, after which he must work a Lunar Observation by both Sun and Star ; determine the Latitude by the Meridian Altitude of the Moon and by the Polar Star *off* the Meridian ; and find the Latitude by double Altitudes of the Sun, and verify the result by Sumner's Method. He must be able to calculate the Altitudes of the Sun, Moon, or Star when they cannot be observed, for the purposes of Lunars; find the Error of a Watch by the Method of Equal Altitudes; and to correct the Altitudes observed with an artifical Horizon.

He must understand how to observe and apply the Deviation of the Compass; and to deduce the Set and Rate of the Current from the D. R. and Observation. He will be required to explain the nature of great Circle Sailing, and know how to apply practically that knowledge, but he will not be required to go into the calculations. He must be acquainted with the Law of Storms, so far as to know how he may probably best escape those tempests (common to the East and West Indies) known as Hurricanes, or Cyclones.

In Seamanship.—The Extra Examination will consist of an enquiry into the competency of the party to heave a ship down, in case of accident befalling her abroad; to get lower masts and other heavy weights in and out; how to construct rafts, and as to his resources for the preser-

vation of the ship's crew in the event of wreck, and in such operations of a like nature, as the Examiner may consider necessary.*

QUALIFICATIONS FOR CERTIFICATES OF COMPETENCY FOR HOME TRADE PASSENGER SHIPS.

A MATE must write a legible hand, and understand the first four rules of Arithmetic. He must know and understand the Rule of the Road, and describe and show that he understands the Admiralty regulations as to Lights. He must be able to take a Bearing by Compass, and prick off the ship's course on a Chart. He must know the marks on the lead line, and be able to work and heave the log.

A MASTER must have served *one* year as a mate in the Foreign or Home Trade. In addition to the qualification required for a Mate, he must show that he is capable of navigating a ship along any coast, for which purpose he will be required to draw upon a Chart, produced by the Examiner, the Courses and Distances he would run along shore from headland to headland, and to give in writing the Courses and Distances corrected for Variation, and the Bearings of the headlands and lights,—and when the Courses should be altered, either to clear any dangers or to adapt it to the coast. He must also understand how to make his soundings according to the state of the Tide.

APPROPRIATE CERTIFICATES.

A person possessing a Master's Certificate, whether of Competency or Service, is eligible to command any vessels of whatsoever tonnage, and either Certificate is sufficient for clearance at the Custom House. But a condition in the Charter-party of vessels taken up by Government, for the conveyance of troops, stores, or emigrants, and also the Regulations of the Principal Steam Packet Companies, require that the Master and principal Officers shall possess Certificates of Competency.

The First Mate may engage as Mate of any kind.

The Only Mate as Mate when there is no other; or as Second Mate, when there is a First Mate.

The Second Mate is not appropriate for any superior station, and must be employed only in cases where a First Mate is also engaged.

A Certificate of Competency for a Foreign-going Ship is equivalent

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* *The Examiner in Seamanship,* by Thomas L. Ainsley, contains full information on this subject, for those preparing for the Extra Examination.

to a Certificate of equal or lower grade for a Home Trade Passenger Ship, and entitles the holder to fill the situation of Master or Mate, as the case may be.

Certificates of Competency or Service may be either of a grade appropriate to the Stations held for the time being, or of any superior grade.

N.B.—CAUTION TO OFFICERS PROCURING CERTIFICATES OF CHARACTER FROM OWNERS AND CAPTAINS:—Certificates of Character from Owners and Captains, must particularly include the word "Sobriety," as they cannot otherwise be received by the Examiners at the Local Marine Board.

VOLUNTARY EXAMINATIONS IN STEAM.

Arrangements have been made for giving to those Masters, or First, or only Mates, who possess Certificates of Competency, or who may apply for such Certificates, and who desire it, an opportunity of undergoing an examination as to their practical knowledge of the use and working of the Steam Engine.

These Examinations are conducted in connection with the other Examinations, in the premises and under the superintendence of the Local Marine Boards, at such times as they may appoint for the purpose; and the Examiners are selected by the Board of Trade, from the Engineer Surveyors appointed under the Merchant Shipping Act, 1854.

The Examination is *viva voce* and will not comprise intricate theoretical questions, but will be such as to satisfy the Examiners that the applicant is competent to control the working of the engine, and has such a knowledge of the ordinary parts of the machinery, as will enable him to judge of the nature of an accident, and, in the absence of the Engineer, to give the necessary directions in the engine room.

Any such person desiring to be so examined must deliver to the Shipping Master a statement in writing to that effect on the Schedule (or form) E.E. If he is already possessed of the requisite Certificate of Competency, he must deliver this statement to the Shipping Master, with his Certificate. Notice will be given of the time at which the applicant is to attend to be examined; and if he passes, the Board of Trade will cause his Certificate of Competency to be issued, or returned to him with an endorsement recording that he has "*Passed in Steam.*"

He must also, at the same time, pay a fee of one pound; and if he fails, no notice of the failure will be recorded on the Certificate, but *no part of the fee will be returned.*

EXERCISES

IN THE

SIMPLE RULES OF ARITHMETIC

FOR

MASTERS & MATES OF HOME TRADE PASSENGER SHIPS.

EXERCISES IN NUMERATION.

Express in Figures :—

1. Five hundred and ninety-eight.
2. One thousand, seven hundred and eighty-three.
3. Six thousand and eighty-six.
4. Eighty-nine thousand and sixty-three.
5. Six hundred and three thousand, two hundred and forty.
6. Twenty thousand, six hundred.
7. Ninety thousand and ninety-two.
8. Two hundred and four thousand, six hundred and forty-one.
9. Eight hundred thousand and eight hundred.
10. Three million, six thousand and four.
11. Five million, thirty thousand and forty.
12. Seven million, seven hundred thousand and six.
13. Ten million, ten thousand and ten.
14. Seventy million, seven hundred and four thousand, and thirty-two.
15. Forty-five million, three hundred and eighty-seven thousand, and twenty-five.
16. Three hundred and forty-nine million, four thousand and sixty-five.
17. One hundred million, ten thousand and one.
18. Eight hundred and forty-two million, two hundred and forty-eight thousand, four hundred and eighty-four.
19. Nine hundred and nine million, nine thousand and ninety-nine.
20. Two hundred and twenty-two million, and forty.
21. Three hundred and five million, forty thousand and eight.
22. Seven hundred million, seven hundred thousand and seven hnndred.
23. Two hundred and two million, two hundred and two thousand, two hundred.
24. Nine hundred million, and nine hundred.

Express in words:—

1. 123	7. 37654	13. 6030405	19. 55700005	25. 275008005
2. 407	8. 87054	14. 560075	20. 76014059	26. 20084216
3. 783	9. 690006	15. 3000006	21. 6006606	27. 79030284
4. 2760	10. 8047328	16. 1397475	22. 56700505	28. 408076032
5. 5060	11. 8540326	17. 20084216	23. 120015015	29. 401400056
6. 7036	12. 5210007	18. 12870045	24. 202202200	30. 908500060

EXERCISES IN SIMPLE ADDITION.

It is usual in the applications of Arithmetic to express the operation of ADDITION by *signs* invented for the purpose: thus, the sum of 4 and 5 is expressed in the *form* $4 + 5 = 9$, wherein the sign $+$ between 4 and 5 denotes the addition of the latter number to the former, and is read *plus* or *more by*; and the sign $=$ between 5 and 9 expresses the result of such addition to be 9, or the *equality* between the *sum* of the numbers 4 and 5, and the *number* 9; so that the arithmetical *expression* $4 + 5 = 9$ is *read* 4 *plus* 5 *equals* 9. Similarly, $2 + 3 + 7 = 12$, shows the sum of the three numbers 2, 3, 7, to be 12.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
321413	543123	536123	123456	761284	657890	692387	876578
452734	234512	453215	234561	612874	278679	4956	495
130421	713145	1234	345612	8719	5798	87658	54937
3718	104234	4231	456223	46759	67843	769378	8796
24561	36142	51234	561234	587999	488567	5790	358428
341323	3451	613254	612345	987678	37429	87958	768453

(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
987825	916427	695624	986257	985626	372519	586372	148537
736349	625736	538426	427385	796842	463726	477754	697296
856925	346831	827836	514986	915638	298534	638831	526438
734316	857936	735985	726326	809274	851372	951490	723649
827842	735784	216515	915827	444444	319628	479291	859698
936736	426467	859827	734482	913258	738543	863748	852619
842625	849753	910756	386912	872364	497791	376546	419648
759519	358358	683625	219863	410698	345345	356633	777777
846325	647846	745841	391285	742367	679567	459681	999999
987846	386921	526606	842163	946208	161514	453148	555555
333445	666777	888999	615827	807609	131549	567963	724483
335445	666777	888999	736846	915827	761346	313499	952637

(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
662593	846914	516398	425396	567453	169964	145673	197794
395266	415327	854627	674958	654359	435434	366535	543543
841923	723456	735829	827694	531769	744315	679654	765976
356627	674216	916358	731045	765453	476757	341345	415161
725983	328427	827146	556677	147954	496059	569765	954131
346783	736259	633289	889900	645679	695969	694313	643167

25. Add together three hundred and nine million, four hundred and seventeen thousand, and eighty-seven; six hundred and seventy-five thousand, and forty-nine; seven thousand and ninety-seven million, eight hundred and fourteen thousand, three hundred and five; seventy-nine million, five hundred and four thousand, and forty-nine; six thousand and seventy-eight million, four hundred and thirty-nine thousand, six hundred and forty-seven; seven thousand million, eight hundred and seventy-six thousand, four hundred and twenty-nine.

EXERCISES IN SIMPLE SUBTRACTION.

The operation of SUBTRACTION is indicated or expressed by the sign —, which is read *minus* or *less by*, with the use of the sign =; thus, the excess of 7 above 5 will be expressed in the *form* $7 - 3 = 4$, which is *read* 7 minus 3 equals 4: where the sign — between 7 and 3 denotes the subtraction of the latter from the former, and the sign = between 3 and 4 shows the *equality* of the excess to 4.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
706205	804601	980001	600501	702001	601002	501001	602004
84694	265061	980000	600492	26000	46003	20106	11006

(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
701628	508000	403000	393436	321298	345876	206011	123456
20449	'129	26001	219050	213788	123457	48605	65432

(17)	(18)	(19)	(20)	(21)
36479236472	3642364231	7631026341	3462364284	23476212861
28217993216	1284128417	5624736794	2698768796	17467127437

(22)	(23)	(24)	(25)	(26)
32179836472	347986312101	7987642062	10110011010	47986321789 6
22222222222	269887360189	486428462	1001110101 1	241826424862

(27)	(28)
10100011101011	37821936211 2
1011100110110	2468676242 1

EXERCISES IN SIMPLE MULTIPLICATION.

The operation of MULTIPLICATION is expressed by the sign ×, which is read *into*, or *multiplied by*; thus, $5 \times 7 = 35$ denotes the result of the multiplication of 5 by 7 to be 35; so again, $4 \times 5 \times 13 = 260$ expresses the continued product of 4, 5, and 13.

1. 342647896 × 2	5. 91823740526 × 6	9. 987654321 × 10
2. 654321987 × 3	6. 6521734782 × 7	10. 891237654 × 11
3. 376543198 × 4	7. 485868788 × 8	11. 647853291 × 12
4. 379865782 × 5	8. 573241789 × 9	12. 918273654 × 12

13. 58726341×23
14. 78954236×34
15. 98765240×57
16. 93876129×95
17. 50014000×270
18. 78965430×700
19. 43679854×806
20. 67869578×903
21. 23589647×678
22. 86483279×567
23. 5832764985×4689
24. 735865000×30700
25. 958866×804002
26. 773289×60503
27. 437743×603004
28. 58640987×98067
29. 5906408×90064
30. 93400×67407
31. 38926392×77
32. 29362983×84
33. 685732×15
34. 903421×18
35. 356628×36
36. 838777×48
37. 777838×49
38. 434560×56
39. 735846×64
40. 279819×72
41. 356718×81
42. 817938×96

EXERCISES IN SIMPLE DIVISION.

The operation of DIVISION is expressed by the sign $\div$, which is read *by* or *divided by;* thus, $42 \div 7 = 6$, implies that the result of the division of 42 by 7 is 6.

1. $135792695 \div 2$
2. $584697386 \div 3$
3. $399345884 \div 4$
4. $298244760 \div 5$
5. $400678593 \div 6$
6. $276586437 \div 7$
7. $6947421006 \div 8$
8. $2470263075 \div 9$
9. $254096106 \div 10$
10. $1101182267 \div 11$
11. $1095137170 \div 11$
12. $59437055212 \div 12$
13. $6489275432689467 \div 14$
14. $5984327896483207 58 \div 22$
15. $569834756892 68 \div 36$
16. $9357864837986496 \div 50$
17. $5986432685946896 \div 63$
18. $987654321012345 \div 66$
19. $9357864837986496 \div 70$
20. $4837958649732067 89 \div 120$
21. $35913213916219 11 \div 132$
22. $4902550716552769 \div 144$
23. $987654321670 \div 3000$
24. $17932810740000 \div 2600$
25. $14710962989869 \div 1709$
26. $27410012221749999 \div 37009$
27. $14977800792352 6 \div 618934$
28. $42243968241835 \div 872169$

MISCELLANEOUS.

1. Express in figures, ten thousand and four.
2. $29483 + 7648 + 32479 + 586 + 298364$.
3. From 6794006897 take 3985160534.
4. Multiply 94785830 by 78060.
5. Divide 5688208152 by 594.
6. Express in figures, one hundred million, one hundred thousand and one hundred.
7. Add together 90473, 9456, 268, 9, 45694, 4, and 87668497.
8. Find the difference between 10000000000 and 87649786.
9. Multiply 326904678 by 3060900.
10. Divide 236487698743 by 85409.
11. Express in figures, one hundred and three million, eighty thousand, two hundred and seven.
12. Add together 69074, 6745, 723, 29, 931648, 9005, and 76245.
13. From 78600070000 take 6974208506.
14. Multiply 167409678 by 768900.
15. Divide 600000070064 by 987065.

ON LOGARITHMS.

(1) Numbers such as 25, 100, 5984, 59864, &c., are called *whole* numbers or *integers*, in distinction to such numbers as $4\frac{3}{4}$, $\frac{3}{8}$, ·5, ·94, ·008621, &c., &c.

(2) Numbers such as ·5, ·69, ·4534, &c., are called decimal fractions, and are less than unity, or one.

(3) Numbers made up of whole numbers and fractions, either vulgar or decimal, are called mixed numbers: for instance, 368·414 is a mixed number, the figures which precede the decimal point (the 3, the 6, and the 8) are whole numbers or integers, while those which follow the point (·414) are decimals.

(4) Figures, when opposed to cyphers, are called *significant*. Thus: in 864000, the 4 is the last significant figure; in ·000193, 1 is the first significant figure.

(5) In every whole number (No. 1) let a decimal point be understood after the unit's place. Thus: 58 is 58·0, or 58·00, &c.

(6) Take any whole numbers, as 18, 813, 6489; the first consists of two, the second of three, and the third of four figures or *digits*. Again, in the mixed number 739·815, the whole number or integral part (739) consists of three *digits*.

(7) LOGARITHMS are numbers calculated for the purpose of facilitating numerical operations by converting multiplication into addition and division into subtraction.

(8) In a system of logarithms all numbers are considered as the powers of some one number arbitrarily assumed, which is called the BASE of the system, and the exponent of that power of the base which is equal to any given number, is called the LOGARITHM of that number.

In the common system of logarithms unity is assumed to be the logarithm of 10; that is, 10 is the constant base. All the logarithms registered in the Tables commonly used, are indices of the radix or base 10; a table of logarithms of numbers is in fact nothing more than a table of the exponents of 10 placed against the several numbers themselves. Accordingly—

0	is the log. of	1,	because	1	is	10^0
1	,,	10,	,,	10	,,	10^1
2	,,	100,	,,	100	,,	10^2
3	,,	1000,	,,	1000	,,	10^3
4	,,	10000,	,,	10000	,,	10^4

Now, if the above Tables were amplified by the insertion of the logarithms of all the numbers between 1 and 10, between 10 and 100, &c., we should have a Table of Logarithms of all numbers from 1 to 10000; and, whatever may be the difficulty of determining the intermediate logarithms, it is at once easily seen that the logarithms of all numbers between 1 and 10 will be 0 + a fraction, of all numbers between 10 and 100 will be 1 + a fraction, of all between 100 and 1000 will be 2 + a fraction, and so forth; or the integral part of each intermediate logarithm will be *one less* than the number of integral figures in the quantity of which it is the logarithm. Thus, the logarithms of 2, 3, 4, &c., to 9, have 0 as the integral part; those of 10, 11, 12, &c., to 99, have 1 as the integer; those of 100, 101, 102, &c., to 999, have 2 as the integer; and so forth. Hence Tables of Logarithms usually supply only the fractional or decimal part; the integral part is always known from the number of integers in the value whose logarithm is wanted.

(9) The logarithm of a number consists of two parts which are separated by a decimal point; the part to the left of the decimal point is a whole number or integer, and is called the *characteristic* or *index;* while the remaining portion which stands to the right of the point is a decimal fraction and is called the *mantissa,* and sometimes the *decimal part.*

EXAMPLE.—In the log. 4·616339, the figure (4) standing to the left of the decimal point is the *characteristic* or *index,* and the remaining portion (·616339) is the *mantissa* or *decimal point.*

The integers 1, 2, 3, 4, &c., which are the logarithms of 10 and its powers, are chief indices; and the logarithms intermediate to these (as for instance 1·90309, which is the logarithm of 80), consisting of an integer and a fraction, though they are also indices, are usually referred to as consisting of an index and mantissa; the integral part being specially termed the *index* or *characteristic,* because it indicates, by being *one less,* how many integral places are in the corresponding natural number; and the annexed decimal part being called the *mantissa,* which is a Latin word signifying an additional handful, something over and above an exact quantity Thus, in the logarithm 80, the index is 1, the mantissa ·90309.

(10) The mantissa or decimal part of the logarithm of any number above 100 is all that is registered in the tables, the characteristic being found as follows:—

RULE I.

The characteristic of the logarithm of a number greater than unity, is one less than the number of the digits of its integer part.

Thus: the characteristic of the logarithm of 849 is 2; for the number 849 is an integer consisting of three digits, and 1 less than 3 is 2. Again, the index of log. of 2649·6 is 3, since the integral part of the number, namely 2649, consists of 4 figures, and 1 less than 4 is 3.

The *Index* of the log. of					The *Index* of the log. of				
24 (in which there are 2 digits) is				1	22·8 (in which there are 2 digits) is				1
3249	,,	4	,,	3	3·158	,,	1	,,	0
149·6	,,	3	,,	2	42748	,,	5	,,	4
14·96	,,	2	,,	1	427·486	,,	3	,,	2
1·496	,,	1	,,	0	10000	,,	5	,,	4
729806	,,	6	,,	5	729·806	,,	3	,,	2

It has been shown before that in the common system (Briggs') the logarithm of 1 is 0; consequently if we wish to extend the application of logarithms to fractions, we must establish a convention by which the logarithms of numbers less than unity may be represented by numbers less than zero, *i.e.* by *negative numbers.*

Extending, therefore, the above principles to negative exponents, since

$$10^{0} = 1 = 1 \qquad 0$$

$$10^{1} = \frac{1}{10} = 0{\cdot}1 \qquad \bar{1} \text{ is the logarithm of } {\cdot}1 \text{ in this system.}$$

$$10^{2} = \frac{1}{100} = 0{\cdot}01 \qquad \bar{2} \quad ,, \quad {\cdot}01 \quad ,,$$

$$10^{3} = \frac{1}{1000} = 0{\cdot}001 \qquad \bar{3} \quad ,, \quad {\cdot}001 \quad ,,$$

$$10^{4} = \frac{1}{10000} = 0{\cdot}0001 \qquad \bar{4} \quad ,, \quad {\cdot}0001 \quad ,,$$

&c., &c.

It follows from this, that the logarithm of every number between 1 and ·1 is some number between 0 and — 1; the logarithm of every number between ·1 and ·01 is some number between — 1 and — 2; the logarithm of every number between ·01 and ·001 is some number between — 2 and — 3, and so on.

The characteristics of the logarithms of all numbers less than unity are negative, and may be found by

Rule II.

The Characteristic of the logarithm of a number less than unity, and reduced to the decimal form, is negative and one greater than the number of cyphers following the decimal point.

A negative characteristic is denoted by writing over it the negative sign (-), thus $\bar{1}$, $\bar{2}$, $\bar{3}$, &c.

Thus the characteristic of the logarithm of ·00521 is $\bar{3}$, since the number of cyphers following the decimal point increased by 1 is 3.

Similarly the index of log. of ·156 is $\bar{1}$.
,, ,, ·0156 is $\bar{2}$.
,, ,, ·00046 is $\bar{4}$.
,, ,, ·000000721 is $\bar{7}$.

But in order to avoid the confusion that might arise by the addition and subtraction of *negative* indices, the following rule is frequently used.

Rule III.

Add 1 *to the number of cyphers between the decimal point and the first significant figure, and subtract from* 10; *the remainder is the index required.*

Thus the characteristic of the log. of ·04 is $\bar{2}$ or 8, since 1 added to the number of cyphers following the decimal point is 2, then 2 from 10 is 8.

Similarly the index	of the log.	of ·140	is	9.
"	"	of ·0149	is	8.
"	"	of ·00064	is	6.
"	"	of ·000000721	is	3.

If the index of a vulgar fraction is required, it must first be reduced to an equivalent decimal fraction, and then the index is found by the rule.

Thus, the index	of log. $\frac{1}{8}$,	or of log. ·125	is $\bar{1}$ or 9.
"	of log. $\frac{1}{25}$,	or of log. ·04	is $\bar{2}$ or 8.
"	of log. $24\frac{2}{5}$,	or 24·4	1.

An alteration in the position of the decimal point alters only the characteristic, and not the decimal part of the logarithm, if the significant figures remain the same; thus all the following numbers and fractions have the same decimal part in their logarithms, with different characteristics:—

·000256	2·56	25600
·00256	25·6	256000
·0256	256	2560000
·256	2560	25600000

This is, for the purposes of numerical calculation, the decisive advantage the base 10 possesses over any other. It is plain then, that one calculation gives us the logarithm of the above numbers, and in fact of as many numbers as can be made by shifting the decimal point to different positions in the combination 2, 5, 6,; but if we adopt any other base, we should require a separate calculation for each of them. The student will perceive that the base 10 has this advantage, in consequence of our system of notation being decimal. If our system were duodecimal, our logarithms would then have to be calculated to the base 12 to be possessed of the like advantage, and so on for any other system.

The characteristic may also be found as follows:—

Rule IV.

Place your pen between the first and second figure (not cypher), *and count one for each figure or cypher, until you come to the decimal point, the number*

thus given will be the characteristic: but observe that if you count to the left *you must subtract the number found from* 10, *and consider the remainder as the characteristic.*

Thus, in finding the log. of 4·6017, if you place your pen between the first figure (4) and second (6), it falls on the decimal point, in this case the characteristic is 0. Next in the case of log. of 4601·7 place your pen between 4 and 6 and count $\begin{array}{l|l} 4 & 601{\cdot}7 \\ & 123 \end{array}$ the characteristic is 3. Next in the case 4601700, here the decimal point falls behind the last cypher (No. 5). Hence, counting as before, we have $\begin{array}{l|l} 4 & 601700 \\ & 123456 \end{array}$ and the characteristic is 6.

Again in the case of log. ·00046017 the first significant figure is 4. Hence, counting, we have $\begin{array}{r|l} {\cdot}0 & 0046017 \\ 4 & 321 \end{array}$, but here we count to the left, so that the characteristic is negative, or $\bar{4}$, which taken from 10 is 6. Again in the case of log. of ·46017, we have $\begin{array}{r|l} {\cdot}4 & 6017 \\ 1 & \end{array}$, and the characteristic is $\bar{1}$, or 9.

LOGARITHMIC TABLES.

The tables containing the logarithms of numbers give them, most frequently, to six places of decimals, as shown in Raper's Navigation, Table 64, and Norie's Epitome, Table 24.

If the number be given, its logarithm may be found as follows:—

To find the logarithm of a number consisting of not more than two digits, *i.e.*, does not exceed 100.

Rule V.

Seek for the number in the column at the top of which is No., *and the decimal part of the logarithm will be found opposite to it in the next column to the right hand.* Prefix the proper characteristic to the mantissa, see Rules I and II, page 17. The result is the logarithm sought.

Ex. 1. Required the logarithm of 21, 2·1, ·21, and ·021.

In the first page of the Table, and in one of the vertical columns marked No., we find the 21, against which stands 1·322219, the logarithm sought. Since the mantissa of the logarithm of any number consisting of the same figures is the same whether the number be integral, fractional, or mixed, the logarithms of the numbers 2·1 and ·021 will have the same decimal part as 21, consequently the logarithm of 2·1 is 0·322219, and the logarithm of ·021 is 8·322219.

Ex. 2. To find the logarithm of 52, 5·2, ·52, and ·00052:—

In the Tables we find the log. of 52 is 1·716003, and, therefore, simply changing the index, the log. of 5·2 is 0·716003, ·52 is 9·716003, and the log. of ·00052 is $\bar{4}$·716003 or 6·716003.

Nat. No.		Logarithms.	Nat. No.		Logarithms.
5	*Ans.*	0·698970	94	*Ans.*	1·973128
9	..	0·954243	½ or ·5	..	$\bar{1}$·698970 or 9·698970
0·009	..	$\bar{3}$·954243	¾ or ·75	..	$\bar{1}$·875061 or 9·875061
0·01	..	$\bar{2}$·000000	2·5	..	0·397940
·0001	..	$\bar{4}$·000000	·25	..	$\bar{1}$·397940
14	..	1·146128	·09	..	$\bar{2}$·954243
41	..	1·612784	·0091	..	$\bar{3}$·959041
2·4	..	0·380211	25·0	..	1·397940
·004	..	$\bar{3}$·602060 or 7·602060	·024	..	$\bar{2}$·380211 or 8·380211
24	..	1·380211	·000035	..	$\bar{5}$·544068 or 5·544068
·24	..	$\bar{1}$·380211 or 9·380211	·000057	..	$\bar{5}$·755875
·0021	..	$\bar{3}$·322219 or 7·322219			

To find the logarithm of a number consisting of not more than three places of figures (from 100 to 1000).

RULE VI.

Find the given number in the vertical column marked No. *at the top, and under* O *will stand the mantissa or decimal part of logarithm.* Prefix the characteristic according to Rules I and II. The result is the logarithm sought.

Ex. 1. Required the log. of 476, 4·76, and ·00476.

We seek in the left hand column of the Table for 476, against which in the column marked O at the top, stands the mantissa corresponding thereto; and this part by the rule is the same for each of the above numbers. Now prefixing the index according to the number of integral figures in the natural number, we find the log. of 476 is 2·677607; of 4·76 is 0·677607; and of ·00476 is 7·677607.

Nat. No.		Logarithms.	Nat. No.		Logarithms.
100	*Ans.*	2·000000	4·80	*Ans.*	0·681241
145	..	2·161368	8·96	..	0.952308
2·94	..	0·468347	1·47	..	0·167317
361	..	2·557507	·147	..	$\bar{1}$·167317
673	..	2·828015	·901	..	$\bar{1}$·954725
794	..	2·899820	·0147	..	$\bar{2}$·167317
982	..	2·992111	424	..	2·627366

If the number contains four places of figures, the logarithm is found by

RULE VII.

The first three figures will be found in the vertical column to the left marked No., *and the fourth in the horizontal column at the top of the page. Under this last, and opposite the three figures, will be found the mantissa of the logarithm sought.* Prefix the index according to Rules I and II. The result is the logarithm sought.

Ex. 1. Required the logarithm of 4587 and of 0·0004587.

The first three figures (viz. 458) being found in the column to the left marked No., and the fourth (7) at the top of the page, the decimal part of logarithm (·661529) is found in the same horizontal line as the three first figures of the given number, and in the same column as the fourth. The index is 3, being one less than the number of *integers* in the whole number: whence the completed logarithm is 3·661529. The logarithm of ·0004587 is $\bar{4}$·661529, the characteristic being negative, and one more than the number of prefixed cyphers.

Nat. No.		Logarithms.	Nat. No.		Logarithms.
1000	*Ans.*	3·000000	94·87	*Ans.*	1·977129
1234	..	3·091315	7·777	..	0·890812
2345	..	3·370143	987·6	..	2·994581
5432	..	3·734960	·06843	..	$\bar{2}$·835247 or 8·835247
26·06	..	1·415974			
2.606	..	0·415974	·002784	..	$\bar{3}$·444669 or 7·444669
·01011	..	$\bar{2}$·004751			

If the number consists of more than four figures, we use

Rule VIII.

1°. *Cut off the first four figures and consider the rest as a decimal.*

2°. *Find the mantissa corresponding to the first four figures.*

3°. *Multiply the tabular difference by the decimal cut off; but at the same time adding unity if the highest cut off is not less than 5.*

4°. *Add the integer part of this product to the figures of the mantissa just found.*

The result is the mantissa of the required logarithm.

The characteristic or index is found by Rules I and II, page 17.

Ex. 1. Required the logarithm of 28434.

Tab. diff.	
153	Mantissa of 2843 = ·453777
× 4	Tab. diff. 153 × 4 = 61·2 = + 61
	Characteristic 4
61,2 or 61	The log. of 28434 = 4·453838

We seek in the left hand column of the Table for 284 (the first three digits) and also at the top of the page in one of the horizontal columns we find 3 (the fourth figure), then in a line with the former and in the column with the latter at the top we have 453777, which is the mantissa of 2843. In a line with the quantity and in the right hand column marked Diff., stands tab. diff. 153; which multiplied by 4, the remaining digit of the given number, produces 612; then cutting off one digit from this (since we have multiplied by only *one* digit) it becomes 61, which being added to 453777 (the mantissa of 2843) makes 453838, and, with the characteristic, 4·453838 the required logarithm.

The logarithm of 284·34 is 2·453838, and the log. of .028434 is $\bar{2}$·453838 or 8·453838.

Ex. 2. Required the logarithm of 12806.

Tab. diff.	Mantissa of 1280	=	·107210
338	Tab. diff. 338 × 6 = 202·8	=	+ 203
× 6	Characteristic	=	4
202,8 or 203	The log. of 12806	=	4·107413

Ex. 3. Find the logarithm of 873457.

Tab. diff.	Mantissa of 8734	=	·941213
50	Tab. diff. 50 × 57 = 28·50	=	+ 29
× 57	Characteristic	=	5
28,50 or 29	The log. of 873457	=	5·941242

The mantissa of the first four figures is found thus:—opposite the 873 and under 4 stands 941213, then in the right column in a line with this stands the Diff. 50, which being multiplied by 57, the remaining digits of the given number, makes 2850; from this we cut off *two* digits to the right (since we have multiplied by *two* digits), when it becomes 28; but as the highest digit cut off is 5, we add unity, which makes 29. Then 5·941212 (the logarithm of 8734) + 29 = 5·941242 is the required logarithm.

Ex. 4. Required the logarithm of 628007.

Tab. diff.	Mantissa of 6280	=	·797960
69	Tab. diff. 69 × 07 = 4·83	=	+ 5
× 07	Characteristic	=	5
4,83 or 5	The log. of 628007	=	5·797965

The log. of 628·067 is 2·798006, and the log. of ·00628067 is $\bar{3}$·798006 or 7·798006. The mantissa of the log. of each of these numbers being the same, the index only being varied (See Rules I and II).

Nat. No.		Logarithms.	Nat. No.		Logarithms.
38475	*Ans.*	4·585179	24800	..	4·394452
384·75	..	2·585179	·056214	..	$\bar{2}$·749845 or 8·749845
12345	..	4·091491			
543·21	..	2·734968	·0098563	..	$\bar{3}$·993714 or 7·993714
66666	..	4·823904			
98765	..	4·994603	643786	..	5·808742
84321	..	4·925936	1129·06	..	3·052717
86400	..	4·936514	384·757	..	2·585186
435·60	..	2·639088	123498	..	5·091660
78·604	..	1·895445	856324	..	5·932638
327·11	..	2·514693	221799	..	5·345960
2·2055	..	0·343508	365152	..	5·562474
15·438	..	1·188591	6·39459	..	0·805813
32·564	..	1·512737	997·1370	..	2·998755
50800	..	4·705864	32·1908	..	1·507732
10000	..	4·000000	448000	..	5·651278
200000	..	5·301030	·0000448	..	$\bar{5}$·651278

The logarithm of a vulgar fraction is the result of the subtraction of the logarithm of its denominator from that of its numerator; because

the fractional form always denotes the division of the quantity above the line by that below it.

Thus:—To find the log. of $\frac{27}{38}$.

$$\begin{aligned} \text{Log. } 27 &= 1{\cdot}431364 \\ \text{Log. } 38 &= 1{\cdot}579784 \\ \hline \text{Log. } \tfrac{27}{38} &= \bar{1}{\cdot}851580 \\ &\text{or } 9{\cdot}851580 \end{aligned}$$

Here the learner may require some explanation respecting the index of the answer. When, in subtracting, he comes to the place of tenths, the process is 1 carried to 5 makes 6, which subtracted from 14 leaves 8; then 1 carried to 1 makes 2, which subtracted from 1 leaves $\bar{1}$, that is, 1 still to be subtracted; the characteristic of the quotient: but as observed (foot of page 17) to avoid negative characteristics, borrow 10, whence the index is 9.

Nat. No.		Logarithms.	Nat. No.		Logarithms.
$90\frac{1}{25}$	*Ans.*	1·954435	$387\frac{1}{3}$	*Ans.*	2·588272
$1000\frac{1}{125}$	..	3·000003	$726\frac{1}{4}$	..	2·861086
$1000\frac{1}{2}$	..	3·000216	$75\frac{7}{8}$	..	1·880099
$\frac{1}{2000}$	..	$\bar{4}{\cdot}698970$ or 6·698970	$\frac{2}{3}$	..	$\bar{1}{\cdot}823908$
			$\frac{2}{3}\cdot\frac{1}{1}\frac{7}{8}$	..	9·833169

If the logarithm be given the number which corresponds to it may be found by the following rules, which are the converse of those last given for finding the logarithm when the number is given.

Since the characteristic denotes how many places the first significant figure stands to the right or left of the units' place; conversely, therefore, if logs. be given having for characteristics 1, 2, 3, ... $\bar{1}$, $\bar{2}$, $\bar{3}$, ... there are in the integral parts of the number to which these logs. belong, 2, 3, 4, ... 0, $\bar{1}$, $\bar{2}$, ... digits respectively. In illustration of these remarks take the following:—

Log.		(in which characteristic)	gives
4·589950		4	38900
3·589950	....	3 ..	3890
2·589950	....	2 ..	389
1·589950	....	1 ..	38·9
0·589950	....	0 ..	3·89
$\bar{1}{\cdot}589950$ or 9·589950	....	$\bar{1}$ or 9 ..	·389
$\bar{2}{\cdot}589950$ or 8·589950	....	$\bar{2}$ or 8 ..	·0389
&c.			&c.

To find the place of the decimal point proceed as follows:—

Rule IX.

Add* 1 *to the index of the given logarithm, and mark off to the left the number of figures for whole numbers, the rest (if any) will be decimals.

Thus: if the index of a logarithm be 2, the natural number contains three integral places, and so on: the rest of the figures (if any) in the natural number taken out are decimals.

The number corresponding to a logarithm with a negative index is wholly decimal, and the number of cyphers following the decimal point is one less than the characteristic of the logarithm.

Thus: if the index is $\bar{4}$, prefix three cyphers to the figures taken out of the table; if $\bar{2}$, prefix one cypher; if $\bar{1}$, the decimal point is placed next the figures taken out.

But instead of the negative characteristic its *arithmetical* complement is sometimes used, in which case we proceed by

Rule X.

Add 1 *to the index, and subtract the number thus found from* 10, *the remainder is the number of cyphers to be prefixed to the figures taken out of the tables. Place the dot before the first cypher.*

Thus, if the index is $\bar{3}$ or 7, 1 added to 7 is 8, then 8 from 10 leaves 2; whence we prefix two cyphers to the number taken out of the table before placing the decimal point.

When the mantissa or decimal part of the logarithm can be found in the table, we proceed by

Rule XI.

1°. *Seek out the mantissa, and take from the column* No. *the three figures in the same horizontal row.*

2°. *From the head of the column take the fourth figure.*

3°. *From the characteristic or index find by the rules already given the position of the decimal point.*

(a) When the characteristic of the given logarithm requires a greater number of digits to the left of the decimal point than there are in the number found by the above rule, the deficiency is made up by adding a sufficient number of zeros (cyphers) to the right.

Examples.

Given the logarithm 2·698970, to find the natural number.

Entering the table with the decimal part ·698970, we find the natural number corresponding to it to be 5, or 50, or 500, or 5000, &c., but as the index of the logarithm is 2, the natural number must contain three integral figures. Hence the natural number of 2·698970 is 500.

Given the logarithm $\bar{3}$·539954 or 7·539954; find the number.

Entering the table with the decimal part, we find the corresponding number is 3467; to this we prefix two cyphers, since the index is $\bar{3}$; or adding 1 to 7, and subtract 8 from 10, we have 2, the number of cyphers to be prefixed, and then the decimal point; hence the number corresponding to 7·539954 is ·003467.

What number corresponds to the logarithm 4·214314.

The decimal part of the log. being found opposite 163 and under the figure 8 at the top of the page; therefore the digits of the required number are 1638. But as the characteristic is 4, there must be in it 5 places of integers. A cypher is annexed (see Rule XI, *(a)*). Hence the required number is 16380.

Required the natural numbers corresponding to logs. 0·176091, and $\bar{4}$·176091.

(1). The mantissa ·176091 stands in the table opposite 150, and in the column with 0 at the top; and the characteristic 0 shows that one of these is integral, whence the number sought is 1·500 or 1·5 (see Rule IX, page 23).

(2). The mantissa of second log. being the same as that of the first, the corresponding number will consist of the same significant figures, but the characteristic $\bar{4}$ shows that the first significant figure (1) must occupy the fourth place to the right of the decimal point, whence the number sought is ·00015.

Required the natural numbers whose logarithms are respectively 1·813514, ·30341, 4·996993, and $\bar{2}$·299943 or 8·299943, we shall find them to be as follows:—

1·813514	=	log. of	65·09
·303412	=	..	2·011
4·996993	=	..	99310
$\bar{2}$·299943 or 8·299943	=	..	·01995

Where it will be observed that the first answer must contain only two integers, as the index of the given logarithm is 1; that the second must contain only one integer, as the characteristic is 0; that the third must consist of five integers, because the index of the given logarithm is 4, and therefore to 9931, the number found in the table, a cypher is annexed; and that the fourth answer must be a decimal, having the first significant figure two places to the right of the decimal point, because the characteristic is $\bar{2}$.

Log.		Nat. No.
0·477121	....	3
0·903090	....	8
0·041393	....	1·1
1·301030	....	20
0·973128	....	9·4
1·161368	....	14·5
2·815578	....	654
0·812245	....	6·49
2·767898	....	586
0·394452	....	2·48
3·091315	....	1234
3·898506	....	7916
2·538574	....	345·6
3·370143	....	2345
1·394977	....	24·83
3·845098	....	7000
3·760422	....	5760
5·825426	....	669000
5·602060	....	400000

Log.		Nat. No.
$\bar{3}$·551938 or 7·551938	....	·003564
$\bar{1}$·744058 or 9·744058	....	·5547
$\bar{7}$·875061 or 3·875061	....	·00000075
$\bar{3}$·845098 or 7·845098	....	·007
$\bar{3}$·444669 or 7·444669	....	·002784
$\bar{2}$·621488 or 8·621488	....	·04183
$\bar{3}$·810904 or 7·810904	....	·00647
$\bar{3}$·662758 or 7·662758	....	·0046
$\bar{3}$·551938 or 7·551938	....	·003564
2·857332	....	·000000072

When, as usually happens, the mantissa cannot be found in the tables, we proceed by

Rule XII.

1°. *Having found the next lower mantissa in the tables, note the four figures which correspond to it.*

2°. *From the given logarithm subtract that taken out of the tables, divide the remainder (annexing as many cyphers as there are digits required above four) by the tabular difference, and reduce the quotient to the form of a decimal.*

3°. *To the four figures already found, add this decimal, and shift the decimal point to suit the characteristic of proposed logarithm.*

The result will be the required number.

Given the logarithm 3·54027 to find the natural number.

Given logarithm	3·543027	
Mantissa next lower	·542950	which corresponds to 3491.
Tab. diff. =	124)·7700(62	
	744	
	260	
	248	

Attaching this (62) to the four figures, we have 349162, &c. But as the index is 3, we obtain, by pointing off four figures to the left, 3491·62 the natural number sought.

Given the logarithms 5·654329 and $\bar{2}$·654273 to find the natural numbers.

654273, which corresponds with the natural number 4511, is the logarithm next less than the given one; therefore the first *four* digits of the required number are 4511. Adding two cyphers to 56, the difference between 654273 and the given logarithm, it becomes 5600, which being divided by 96, the *tabular difference* corresponding with 4511, gives 58 as quotient and 32 as remainder. The *integers* of the required number (one more than 5, the characteristic) are, therefore, 451158. The mantissa of the second log. being the same as the first one, the natural number will contain the same significant figures, viz., 451158, but the characteristic $\bar{2}$ shows that the first significant figure of the nat. no. (4) must stand in the second place to the right of the decimal point; therefore, the nat. no. corresponding to $\bar{2}$·654273 is ·0451158.

Let it be required to find the number of which the logarithm is 3·104831.

Given logarithm	3·104831	
Mantissa next lower	·104828	which corresponds with 1273.
Tab. diff. =	341)3000(·008	
	2728	
	272	

Therefore, 3·104831 = log. of 1273·009 nearly. In dividing by tab. diff. we take remainder 3 and a cypher, then 341 in 30 goes no times, which we place down in the

quotient, then taking another cypher we have 300, which contains 341 no times, lastly, 341 goes into 3000 eight times with 272 for remainder. The remainder 272 being more than half the quotient the last figure of the quotient (8) is increased by 1 or unity.

Log.	Nat. No.
2·931214	853·52
3·625343	4220·3
4·851906	71105·9
4·361730	230001
1·725364	53·1329+
1·972521	93·8689+
5·659707	456780
5·734968	543210
5·823904	666660
4·994603	98765
4·925936	84321
5·091512	123456
2·535224	342·945
3·744726	5555·54
5·831835	678945
2·415671	260·418+
4·841989	69500·65

Log.	Nat. No.
1·217845	16·5137
$\bar{3}$·984671 or 7·984671	·0096532
$\bar{4}$·463726 or 6·463726	·00029088
$\bar{2}$·241877 or 8·241877	·0174533
$\bar{3}$·519956 or 7·519956	·00331098
$\bar{1}$·998813 or 9·998813	·997270
$\bar{1}$·895090 or 9·895090	·785398
$\bar{4}$·932847 or 6·932847	·00085673
$\bar{5}$·565942 or 5·565942	·000036808

The arithmetical complement of a number is the number by which it falls short of the unit of the next higher denominator. It is abbreviated into *Ar. co.*

The lowest denominator considered is the unit, thus:—

Ar. co. ·0094 = 1 — ·0094 not ·01 — ·0094 .

The most expeditious way of finding the arithmetical complement is as follows:— *Begin from the left, subtract every figure from 9 up to the lowest significant figure, which subtract from 10. Repeat the cyphers at the end, if any.*

(a) When the characteristic is negative it must be added to 9.

Ex. 1. Find the ar. co. of 1·97043

Ar. co. log. required 8·02957

The ar. co. of 3·607218 is 6·392782
„ „ 0·714000 „ 9·286000
„ „ 5·631642 „ 4·368358

Ex. 2. Find the ar. co. of 9·086540

Ar. co. log. required 0·913460

The Ar. co. of 2·170630 is 7·829370
„ „ (a) $\bar{1}$·217034 „ 10·782960
„ „ (a) $\bar{3}$·178680 „ 12·826320

A subtractive quantity is, by this means, made additive. The process is equivalent to subtracting the number from 10, and the reason of it is evident on considering that to add 3 and subtract 10 is the same as to subtract 7. In like manner, instead of subtracting $42^m\ 10^s$ for example, we may add $17^m\ 50^s$ (the complement to 60^m), provided we subtract 1^h (or 60^m); and thus any number of quantities of which some are additive and some subtractive, may be rendered all additive, provided that the larger numbers which are employed in taking the complements be themselves subtracted.

Degree of Dependence.—The number of places of figures which may be obtained in a result derived from any table of logarithms, is the same usually, rejecting prefixed cypher, as the number of decimals to which the logarithms are carried. But towards

the end of the table the last place thus obtained cannot always be depended upon within a unit, that is, provided the mantissa of log. is greater than ·9388. Thus, for instance, the log. 3·7575 corresponds to the no. 5721 and the log. 3·7576 to 5722, nearly.

This remark should be kept in mind, because it is mere waste of time to employ more figures than are required to insure a certain degree of precision in the result.

MISCELLANEOUS.

We here insert a collection of numbers, the logarithms of which are to be taken out of the tables.

1.	9	13.	700	25.	0·6896	37.	0·09999	49.	547600
2.	5	14.	63·5	26.	0·92096	38.	00058	50.	30000·9
3.	0·1	15.	6390	27.	0·0349	39.	·035872	51.	10000·9
4.	78	16.	8004	28.	0·0899	40.	·057234	52.	594500
5.	90	17.	26·06	29.	6656	41.	93·7654	53.	900000
6.	4·9	18.	2·606	30.	10000	42.	·00085	54.	88590000
7.	10	19.	·1463	31.	10090	43.	52790	55.	0·0098563
8.	38	20.	3·874	32.	79507	44.	50000	56.	287·642
9.	380	21.	6754	33.	48000	45.	700090	57.	0·003564
10.	100	22.	0·0876	34.	72·643	46.	264000	58.	0·056214
11.	0·029	23.	0·3467	35.	15·438	47.	404007	59.	·000856736
12.	917	24.	0·0129	36.	9080·8	48.	500909	60.	0·005693

Required the natural numbers of the following logarithms:—

1.	2·309630	13.	1·565000	25.	1·188591	37.	5·654243	49.	0·763947
2.	3·676968	14.	2·621754	26.	3·020887	38.	0·434294	50.	$\bar{1}$·883030
3.	2·376577	15.	3·786942	27.	$\bar{2}$·954243	39.	$\underline{5}$·606389	51.	3·625343
4.	0·954243	16.	0·565021	28.	$\bar{3}$·959041	40.	$\bar{2}$·397050	52.	1·725364
5.	1·698970	17.	0·778441	29.	4·705864	41.	$\underline{5}$·000000	53.	$\bar{2}$·627407
6.	0·000000	18.	2·769504	30.	1·415674	42.	$\bar{2}$·881955	54.	$\bar{3}$·686216
7.	2·845098	19.	5·774152	31.	0·415974	43.	$\bar{1}$·167317	55.	0·400573
8.	2·000000	20.	5·421604	32.	$\bar{1}$·000000	44.	$\bar{7}$·875061	56.	1·567343
9.	1·944483	21.	3·000000	33.	$\bar{3}$·954243	45.	0·000186	57.	0·927632
10.	2·056905	22.	6·394452	34.	$\bar{2}$.716003	46.	6·947385	58.	$\underline{5}$·002559
11.	2·564494	23.	1·415674	35.	4·000000	47.	$\bar{2}$·963081	59.	$\bar{4}$·321547
12.	3·563362	24.	2·640978	36.	0·230449	48.	$\bar{2}$·564772	60.	0·875061

MULTIPLICATION BY LOGARITHMS.

In multiplication we proceed by

RULE XIII.

1°. *Find the logarithms of the numbers, the product of which is required.* (For the method of taking out the log. of a number, see pages 19 to 22.)

2°. *Add these together, the sum will be the logarithm of the product.*

3°. *Find from the tables the corresponding number.* (For the method of finding the corresponding number to a log., see pages 23 to 25.)

This will be the required product.

(a) When the characteristics of the logs. to be added are both positive, it is evident that their sum will be positive. When they are both negative, their sum (diminished by what is to be carried from the sum of the positive decimal parts) will be negative. When one is negative and the other positive, subtract the less from the greater, and prefix to the difference the sign belonging to the greater.

Examples.

1. Multiply 77 by 100. The log. of 77 and 100 being taken from the table, we have
77 log. 1·886491
100 log. 2·000000

7700 log. 3·886491

We have here added the logs. of the given factors, and having sought in the table for the mantissa ·886491, we have found the figures of the nat. no. corresponding to be 7700; the index 3 determines *four* of these to be integral; hence the product is 7700 (Rule IX, page 23).

2. Multiply 476 by 50.
476 log. 2·677607
50 log. 1·698970

23800 log. 4·376577

The mantissa of log., viz. ·376577, is found *exactly* in the table in a line with 238 and under 0; but as the characteristic 4 requires 5 digits in the integer part, we therefore add a 0 (cypher), which gives 23800 as the nat. no. corresponding to the proposed log. This is according to Rule XI, *(a)*.

3. Multiply 963 by 48·9 by common logarithms. The log. of 963 and 48·9 being taken from the table, we have
963 log. 2·983626
48·9 log. 1·689309

Log. 4·672935
4709 (next lower in tab.) 672929

Product 47090·7 — 92)6·00(06
552

48

We have here added the logs. of the given factors together, and having sought for the given mantissa ·672935, which is not to be exactly found in the tables, we obtain the next less mantissa ·672929, which we subtract from the given mantissa, the difference is 6, to which two cyphers are annexed, and then we divide by the tabular difference 92, whence we obtain 07 nearly; the remainder, 48, being more than half the divisor, 1 is added to the last figure in the quotient (6); attaching these to the four figures obtained previously, we have 470907; the index 4 determines *five* of these to be integral; hence the product is 47090·7 (Rule IX, page 23).

4. Multiply ·0567 by ·00339.
·0567 log. 8·753583
·00339 log. 7·530200

·0001922 log. 6·283783

Or thus, using negative indices:
·0567 log. $\bar{2}$·753583
·00339 log. $\bar{3}$·530200

·000192 log. $\bar{4}$·283783

In adding, when we come to the places of tenths, the process is 5 and 7 are 12, 2 to put down and 1 to carry, and since the indices are both negative $\bar{2}$ and $\bar{3}$, we diminish their sum ($\bar{5}$) by the number carried (1), which leaves $\bar{4}$ for the index (see Rule XIII, *(a)*. We prefix 3 cyphers because the index being $\bar{4}$ the first significant figure of product must stand in the fourth place from the decimal point.

5. Multiply 29·42 by 8·6 by common logarithms.
29·42 log. 1·468643
8·6 log. 0·934498

2·403141
2530 (next lower in tab.) 403120

Product 253·012 — 171)2100(12+

6. Multiply 99·9 by 8·63.
99·9 log. 1·999565
8·63 log. 0·936011

862·136 log. 2·935576

7. Multiply 97 by 83.
97 log. 1·986772
83 log. 1·819078

8051 log. 3·805850

8. Multiply 20 by ·5.
20 log. 1·30103
·5 log. $\bar{1}$·69897

10 log. 1·*0000

Here the 1, which is carried after adding 1, 6, and 3, (where we have placed an asterisk instead of a cypher to mark the place) instead of increasing the $\bar{1}$, destroys it. This is according to Rule XII, *(a)*.

9. Multiply 498 by 376.
498 log. 2·697229
376 log. 2·575188

187248 log. 5·272417
306

Diff. 232)11100(48 nearly.
928

1820
1856

10. Multiply 734 by 23.
734 log. 2·865696
23 log. 1·361728

16882 log. 4·227424
Next lower mantissa 227372

258)520(2
516

11. Multiply 437·8 by 14·07 and 0·239.
437·8 log. 2·641276
14·07 log. 1·148294
0·239 log. 9·378398

1472·20 log. 3·167968

12. Multiply 436 by 19·7.
436 log. 2·639486
19·7 log. 1·294466

8589·2 log. 3·933952

13. Multiply 3654 by 500.
3654 log. 3·562769
500 log. 2·698970

1827000 log. 6·261739
(See Rule XI *(a)*, page 24.)

14. Multiply ·0172 by ·00214.
·0172 log. $\bar{2}$·235528
·00214 log. $\bar{3}$·330414

·0000368o8 log. $\bar{5}$·565942
The sum of the characteristic is taken as they are both negative (Rule XIII, *(a)*.

15. Required the product of 17·25, 0·82, and 0·065.
17·25 log. 1·236789
·82 log. 9·913814
·065 log. 8·812913

0·919425 log. 9·963516

Or thus: 17·25 log. 1·236789
·82 log. $\bar{1}$·913814
·065 log. $\bar{2}$·812913

0·919425 log. $\bar{1}$·963516

Here we have one to carry from the mantissa, which added to the positive index 1 (index of log. 17·25, see above) makes positive 2. Now the sum of the negative indices is $\bar{3}$ (negative 3), and, therefore, since where one is positive and the other is negative the difference is the index; we have + 2 from $\bar{3}$ leaves $\bar{1}$ for the index, and the first significant figure of the quotient must occupy the first place to the *right* of the decimal point (Rule IX, page 24, top).

Examples for Practice.

1. Multiply by logs. 85 by 70; 100 by 10; 39 by 27; 37 by 98; and 97 by 79.
2. Multiply 83 by 77; 100·3 by 12; 38·7 by 3·2; 76·4 by 5·4; and 307 by 3$\frac{1}{10}$.
3. Multiply 38 by 1·74; 601 by 18; 250 by 12·5; 82 by 12; and 101 by 11.
4. Multiply 288 by 24; 517 by 659; 9001 by 90; 5760 by 12; and 970 by 630.
5. Multiply 127 by 304; 476 by 100; 98 by 194; 34 by 6; and 3654 by 500.
6. Multiply 37·6 by 249; 44·4 by 22·2; 182·7 by 250; 39·07 by 20; and 28·9 by 96·5
7. Multiply 76 by 42; 82·33 by 15·3; 47·6 by 6·82; 99·9 by 8·63; and 10000 by 10.
8. Multiply 732 by 543; 8·7 by 6·4; 96 by 5·3; 139 by 240; and 190 by 47·5.
9. Multiply 386 by 288; 12·5 by 35: 98 by 50; 109 by 94; and 307 by 0·84.
10. Multiply 119 by 7·55; 46·4 by 0·85; 457 by 1·6; 5·9 by 99·1; and 23 by 73·4.
11. Multiply 396 by 184; 152 by 25·4; 13·5 by 117; 32·3 by 68; and 563·1 by 42.

12. Multiply 307 by 3·1; 37 by 6·70; 5900 by ·00071; and 23·807 by ·02.
13. Multiply ·02865 by 2196; ·334387 by ·05454; and ·03948 by 9·1959.
14. Multiply ·1 by ·1; ·01 by ·001; 10 × ·01 × ·001; and 1000 by 100.
15. Multiply ·00146 by ·039; ·02895 by 2196; 4·189 by ·00071; and ·37 by ·670.
16. Multiply 673·14 by 35; 5900 by ·00071; 1000 by 100; and ·00000275 by ·0336.

Required by means of logarithms the product of:—

17. ·002784 × 4 × 1600; 7·84 × ·00083 × ·000027; 52 × 734 × 6.
18. ·37 × 426 × ·004 × ·275 × 326; 72 × 96 × 124 × ·05; and 32 × 181 × 4.
19. 2·4 × ·007 × ·54 × ·1; ·6 × 4 × 1·2 × 32; and 18 × 48 × 6·2 × 4.
20. 36 × 48 × 62 × 4; $286\frac{1}{2} \times 19\frac{3}{5} \times 16\frac{1}{5} \times 4\frac{3}{4}$; and $\cdot 7\dot{7}2 = (\frac{17}{32}) \times \frac{5}{9}$.

DIVISION BY LOGARITHMS.

In division we proceed by

Rule XIV.

1°. *Find the logarithms of the numbers the quotient of which is required.*

2°. *Subtract the logarithm of the divisor from that of the dividend; (adding* 10 *to the index of this last, if required), the difference will be the logarithm of the quotient.*

3°. *Find from the tables the corresponding number.*

This will be the required quotient.

In subtracting the logarithm of the divisor, if it is negative, change the sign of its characteristic, and then proceed as if this were to be added to the characteristic of the dividend; but before making the characteristic of the divisor positive, subtract what was borrowed (if anything), in subtracting its decimal part. For, since the decimal part of a logarithm is positive, what is *borrowed*, in order to make it possible to subtract the decimal part of the logarithm of the divisor from that of the dividend, must be so much taken away from what is positive, or added to what is negative in the remainder. We change the sign of the negative characteristic, and then *add* it; for, adding a positive is the same as taking away a negative quantity.

Examples.

1. Divide 3192 by 76.

The log. of 3192 is taken out according to Rule VII, page 20, and the log. of 76 by Rule V, page 19.

	3192	log. 3·504063
	76	log. 1·880814
Quotient	42·0	log. 1·623249

2. Divide 229008 by 312.

Log. 2290 =	359835	tab. diff.	189
Diff. for 08 +	15		× 08
	359850		15,12
			or 15

229008	log. 5·359850
312	log. 2·494155
734·0	log. 2·865695

3. Divide 830772 by 982.

The log. of 830772 is taken out by Rule VIII, page 21. We seek in the left hand column of the table (No.) for 830 (the first three digits), and also at the top of the page in one of the horizontal columns for the fourth figure 7, then in a line with the first and under the latter we have 919444. In a line with the quantity in the right hand column marked Diff. stands 52, which multiplied by the remaining figures of the nat. number, viz., 72 produces 3744; then cutting off two digits from these (since we multiplied by *two* digits) it becomes 37, which being added to 919444, the mantissa of 8307, makes 919481, and with the characteristic 5, is 5·919481. The work will stand thus:—

Log. 8307	= 919444	tab. diff.	52
Diff. for 72	+ 37		× 72
	919481		104
			364
			37,44

830772 log. 5·919481
982 log. 2·992111

Quotient 846·0 log. 2·927370

4. Divide 111168 by 288.

Log. 1111	= 045714	tab. diff.	390
Diff. for 68 +	265		× 68
	045979		3120
			2340
			265,20

111168 log. 5·045979
288 log. 2·459392

Quotient 386·1 log. 2·586587

5. Divide ·00815 by ·000275.

0·00815 log 7·911158
0·000275 log. 6·439333

Quotient 29·6363 log. 1·471825

Or, ·00815 log. $\bar{3}$·911158
·000275 log. $\bar{4}$·439333

29·6363 log. 1·471825

The index of the divisor $\bar{4}$ being supposed changed to positive 4, the difference between which and $\bar{3}$ leaves positive 1 for index of quotient.

6. Divide 1000·0 by 10·0.

1000·0 log. 3·000000
10·0 log. 1·000000

Quotient 100·0 log. 2·000000

7. Divide 26843 by ·003010.

Log. 2684	= 428782	tab. diff.	162
Diff. for 3 =	+ 49		× 3
Log. 26843 =	428831		48,6
			or 49

26843 log. 4·428831
·03010 log. 8·478566

891794 log. 5·950265
219

49)4600(94 nearly.

Or thus: 26843 log. 4·428831
·03010 log. $\bar{2}$·478566

891794 log. 5·950265

Here the characteristic of the second log. is $\bar{2}$, but following the rule, we have changed it to positive 2. The characteristic of first log. being positive 4, the two are added, the sum being positive 6, but having borrowed 1, the correct characteristic is 5, and being positive, the quotient will contain 6 integral figures.

8. Divide 2407·2 by 24.

2407·2 log. 3·381512
24 log. 1·380211

Quotient 100·3 log. 2·001301

9. Divide 469·76 by 0·937.

496·76 log. 2·671877
0·937 log. 9·971740

Quotient 501·345 log. 2·700137

Or, 469·76 log. 2·671877
0·937 log. $\bar{1}$·971740

501·345 log. 2·700137

10. Divide 579416 by 4324.

Log. of 5794	= 762978	tab. diff.	75
Parts for 16	+ 12		× 16
Log. of 579416 =	5·762990		450
			75
			12,00

579416 log. 5·762990
4324 log. 3·635886

134·0 log. 2·127104

11. Divide 876·32 by 32·567.

	876·32 log.	2·942663
	32·567 log.	1·512777
Quotient	26·9083 log.	1·429886

12. Divide 3672 by 51000.

	3672 log.	3·564903
	51000 log.	4·707570
Quotient	·072 log.	$\bar{2}$·857333

EXAMPLES FOR PRACTICE.

1. Divide 6391 by 77 : 21636 by 36; 6384 by 76; and 31250 by 250.
2. Divide 3600 by 60; 4500 by 9; 3654 by 38; and 58469 by 981.
3. Divide 1755 by 39; 646 by 34; 216·0 by 30; and 365·55 by 5·5.
4. Divide 36808 by 127; 147392 by 440; 72864 by 184; and 16882 by 734.
5. Divide 76·4 by 1·6; 32·08 by 8·8; 69·52 by 2·4; and 1·728 by 1·2.
6. Divide 2020 by 202; 2000 by 2000; 87648 by 368; and 147000 by 1470.
7. Divide 135056 by 734; 8746·9 by 36·4; 674·80 by ·0763; and 3372·36 by 5·37.
8. Divide 236 by 19·1; ·0472 by 3·12; ·03755 by ·025; and 476·14 by 248.
9. 19 ÷ 72; 19 ÷ ·72; 19 ÷ 7·2; and 19 ÷ ·0072.
10. 0·01237 ÷ 108·46; 287642 ÷ 834·56; 472 ÷ 32·2; and 10011·1 ÷ 99·3.
11. 1 ÷ ·0004572; 112221 ÷ 111; 1 ÷ 6·729; and 56262·5 ÷ 52·643.
12. 3256·7 ÷ 129; 585900 ÷ 124; 72384 ÷ 192; and 132·45 ÷ 385.
13. ·0001 ÷ ·0001; ·01 ÷ 001; ·01 ÷ 100; and 1· ÷ ·001.
14. 364·09 ÷ 6·6; 34·56 ÷ ·0024; 4752000 ÷ 3500; and 10000 ÷ 10.

When it is proposed to find the value of an expression in which both multiplication and division are signified, the sum of the logarithms of the factors ot the dividend, diminished by the sum of the logarithms of the factors of the divisor will be the logarithm of the value required.

Thus: to find the value of $\frac{209 \times 573 \times 63}{287 \times 2101}$

209	log.	2·320146
573	log.	2·758155
63	log.	1·799340
		6·877641
		5·780308

287	log.	2·457882
2101	log.	3·322426
		5·780308

Ans.: 12·5122 log. 1·097333

It is very often expedient to transform the logarithm of a divisor into that of a multiplier, and it is customary, in such calculations, to avoid not only negative logarithms, but negative indices also, by substituting for a subtraction logarithm its arithmetical complement *(See page 27)*. This makes the operation consist of a single addition; only we must diminish the result by subtracting 10 for every arithmetical complement that has been used.

To apply this method to the example above:—Having found in the table the log. of the divisor 287, we may at once transform it into the addition logarithm 7·542118, and similarly for the log. of 2101 we may write 6·677574, and then the calculation will proceed continuously as follows:—

209	log.	2·320146	
573	log.	2·758155	
63	log.	1·799340	
287	ar. co.	7·542118	— 10
2101	ar. co.	6·677574	— 10
		1·097333	*Ans.*: 12·5122.

15. $\dfrac{84 \times {\cdot}00769 \times 63}{598{\cdot}00 \times {\cdot}00146 \times {\cdot}039}$ $\qquad \dfrac{2{\cdot}4 \times {\cdot}0035 \times 1{\cdot}08 \times {\cdot}1}{669 \times 4 \times 1{\cdot}483}$

16. $\dfrac{47 \times 140{\cdot}5 \times 84}{{\cdot}002784 \times 4 \times 1600}$ $\qquad \dfrac{95{\cdot}6 \times 158 \times 4{\cdot}96 \times 302}{1289 \times {\cdot}0893 \times {\cdot}00849 \times {\cdot}9}$

17. $\dfrac{121 \times 559 \times 126}{1562 \times 216}$ $\qquad \dfrac{8{\cdot}4 \times {\cdot}0769 \times {\cdot}00683}{59{\cdot}8 \times {\cdot}0000146 \times {\cdot}0039}$

18. $\dfrac{3{\cdot}1416 \times 82 \times \frac{73}{41}}{{\cdot}02912 \times 751{\cdot}3 \times \frac{6}{941}}$ which in a simplified form is $\dfrac{3{\cdot}1416 \times 82 \times 73 \times 941}{{\cdot}02912 \times 751{\cdot}3 \times 6 \times 41}$

19. Divide ·06314 × ·7438 × ·102367 by ·007241 × 12·9476 × ·496523, and compare the result with the product of 8·71979 × ·057447 × ·0206168.

20. $\dfrac{167 \times 15\dot{7} \times 1{\cdot}1\dot{3}\dot{6}}{781 \times 75}$ $\qquad \dfrac{1}{{\cdot}0004405} \times \dfrac{1}{3{\cdot}2} \times \dfrac{1}{{\cdot}2\dot{6}}$

21. $\dfrac{4935\frac{3}{7} \times 8{\cdot}15}{79{\cdot}16\dot{5} \times 7917{\cdot}\dot{0}\dot{6}}$ $\qquad \dfrac{44800 \times 47\frac{13}{25} \times {\cdot}0091 \times {\cdot}4\dot{1}4\dot{8}}{2{\cdot}2\dot{3}6\dot{0} \times 73\frac{23}{35} \times {\cdot}01011 \times 3{\cdot}0\dot{8}1\dot{9}}$

TABLES OF NATURAL SINES, ETC.

Trigonometrical magnitudes are numbers capable of being calculated from geometrical principles, and accordingly, tables, called Tables of Natural Sines, have been computed, in which the values of the Sines, Cosines, &c., of every degree and minute of the quadrant are registered. The statement of the method by which such tables are constructed is unsuited to the present treatise. The mode of using them in computation we shall now proceed to explain. In using these tables we have either to find the sine, cosine, &c., of an angle whose value is given in degrees, minutes, and seconds; or being given the value of the angle in degrees, minutes, and seconds, to find the corresponding value of the sine, cosine, &c.

If the value of the angle be given in degrees and minutes, the sine, cosine, &c., is found directly from the tables, in which are registered the values of trigonometrical quantities.

If the angle contains seconds, we must proceed by the *method of proportional parts*, as in the following examples.

Rule XV.

1°. *Find from the table the nat. sine, cosine, &c., which corresponds to the degrees and minutes.* (Norie, Table XXVI.)

2°. *Multiply the tabular difference by the seconds, and divide by* 100.

3°. *If the required quantity be a nat. sine, tangent, or secant, add the result to the last figures obtained in* 1°*; if it be a cosine, cotangent, or cosecant, subtract.* The result will be the required sine, cosine, &c.

Examples.

1. Find the nat. sine of 12° 44′ 27″.

$$\text{Nat. sine } 12^\circ\, 44' = 220414$$

$$\text{Tab. diff. } \frac{473 \times 27}{100} = +\ 128$$

$$220542$$

Ans.: Sine 12° 44′ 27″ = 220542

To obtain the parts for the seconds we multiply the tabular difference by the number of seconds and divide by 100, thus:—

$$\begin{array}{rr} \text{Tab. diff.} & 473 \\ \text{No. of seconds} & \times\ 27 \\ \hline & 3311 \\ & 946 \\ \hline & 127{,}71 \\ \hline & 128 \text{ nearly} \end{array}$$

To divide by 100 we have merely to cut off the two right hand figures.

2. Find the nat. cosine 31° 28′ 42″.

$$\text{Nat. cosine } 31^\circ\, 28' = \cdot 852944$$

$$\text{Tab. diff. } \frac{253 \times 42}{100} = -\ 106$$

$$\cdot 852838$$

Ans.: Cosine 31° 28′ 42″ = ·852838

$$\begin{array}{rr} \text{Tab. diff.} & 253 \\ \text{Seconds} & \times\ 42 \\ \hline & 506 \\ & 1012 \\ \hline & 106{,}26 \\ \hline & 106 \end{array}$$

The reason of this rule is founded on the principle that for a small interval, such as one minute, the increase of the sine is proportional to the increase of the angle.

Examples for Practice.

To find the nat. sine of

26° 14′ 19″	Nat. Sine	444717	46° 22′ 37″ Nat. Sine	723895
34 48 15	,, ...	570774	76 57 49 ,, ...	974228
60 7 18	,, ...	867085	43 39 55 ,, ...	690455
71 20 43	,, ...	947463	65 23 36 ,, ...	909187
50 0 56	,, ...	766217	53 7 49 ,, ...	8
21 44 21	,, ...	370383	86 3 17 ,, ...	997630

To find the nat. cosine of

18° 19′ 17″	Nat. Cosine	919308	46° 31′ 41″ Nat. Cosine	688000
14 15 3	,, ...	969227	6 53 56 ,, ...	992761
70 47 40	,, ...	328958	29 40 48 ,, ...	868805
80 22 22	,, ...	167237	38 31 10 ,, ...	782397
5 22 10	,, ...	995612	16 12 54 ,, ...	960219

If the value of the sine, cosine, &c., be given, and it is required to find the angle, we use the following rule:—

Rule XVI.

1°. *Find in the tables the next lower nat. sine, nat. cosine, &c., and note the corresponding degrees and minutes.*

2°. *Subtract this from the given sine, cosine, &c., multiplying the difference by* 100, *divide by the tabular difference and consider the result as seconds.*

3°. *If the given value be that of a sine, tangent, or secant, add these seconds to the degrees and minutes found in* 1°, *if it be that of a cosine, cotangent, &c., subtract.* The result will be the required angle.

Examples.

1. Given the natural sine = 0·732156 : find the angle.

Given nat. sine 732156
Sine 47° 4′ = 732147 next lower in table XXVI.

Tab. diff. = 327   327)·900(3″ nearly (additional seconds for nat. sine).
981   *Ans.:* 47° 4′ 3″.

The log. 732156 is sought for in table XXVI, Norie, but as it cannot be found exactly, the next less is taken which corresponds to 47° 4′. The difference of the logs. is then found, two cyphers added (which is equivalent to multiplying by 100), and the product divided by the tabular difference, the quotient is the additional seconds.

2. Given the natural cosine 853267 : find the angle.

Given nat. cosine 853267
Cosine 31° 26′ = 853248

Tab. diff. = 253   253)1900(7″ (to be *subtracted*).
1771
129   *Ans.:* 31° 25′ 53″.

31° 26′ 0″
— 7
31 25 53

Examples for Practice.

Given the nat. sines, to find the angle.

·456480	27° 9′ 37″	·920411	66° 59′ 10″
·898002	63 53 17	·444	26 21 34
·370383	21 44 21	·20389	11 45 46
·8	53 7 49	·740912	47 48 33
·6 or $\frac{12}{20}$	36 52 11	$\frac{163}{308}$ or ·529221	31 57 10
·75	48 35 25		

Given the nat. cosine, to find the angle.

·448807	63° 19′ 58″	·914237	23° 54′ 9″
·948397	18 29 12	·769388	39 42 4
·726998	43 21 53	·974822	12 53 4
·702017	45 24 39	·817726	35 8 32
·514841	59 0 47	·215515	77 33 15
995	5 43 57	·896	26 21 46
$\frac{16}{20}$ or ·8	36 52 12	$\frac{11}{14}$ or ·785714	38 12 47
$\frac{13}{14}$ or ·928571	21 47 12	$\frac{15}{16}$ or ·9375	20 21 51

TABLES OF LOGARITHMIC SINES, ETC.

In order to apply logarithmic calculations to trigonometrical quantities, it is necessary to construct tables of logarithms of the natural sines, cosines, &c., and the real logarithmic sines, tangents, &c., are just the logarithms of those numbers which are the natural sines, tangents, &c.* In practice the logarithmic are generally far more useful than the natural sines, &c., though the latter are often necessary, or, in some simple kinds of calculation, preferable.

As all the sines and cosines, all the tangents from 0° to 45°, and all the cotangents from 45° to 90°, are less than radius or unity; the logarithms of the values of these quantities are decimal fractions and have negative characteristics. In order to avoid the necessity of entering negative numbers, 10 *is added to every logarithm* before it is registered in the tables of logarithmic sines.

Thus, on referring to the table of natural sines (Table XXVI, Norie), we find that sine 16° = 0·275637. If we calculate the logarithm of 0·275637, we find that its value is $\bar{1}$·440338; if to this 10 is added, we find that

$$\text{Log. sine } 16° = 9·440338.$$

In trigonometrical operations this is convenient, but principally because the extraction of roots very seldom occurs. The same thing is done, for the sake of uniformity, with logarithmic tangents, though only those of angles under 45° would, as just stated, have negative indices.

It may be observed here that the uniform addition of 10 to the index gives the logarithm of 10000 *million* times the natural number.

Thus, 9·599327 is the log. of 3979486000, and this latter number is the natural sine corresponding to a radius of 10000 *millions*, instead of a radius of unity.

The table of logarithmic sines, cosines, tangents, cotangents, secants, and cosecants, contain all arcs from 1′ of a degree through all magnitudes up to a quadrant or 90°, the log. of radius as just stated being 10. At the top of the page is placed the number of degrees, and in the left hand column each minute of the degree, opposite to which are arranged the numerical values of the log. sine, cosine, &c., of the corresponding

* There are independent methods of calculating logarithmic tables, but any investigation of these methods would be out of place in these pages.

angle in those columns, at the *top* of which those terms are placed. The headings of the columns run along the *top*, thus as far as 44°. The degrees from 45° to 90° are placed at the *bottom* of the page, and the minutes of the degree arranged in a right hand column, so that the angles read off on the right hand side are complementary to those read off at the points exactly opposite on the left hand side, the values of the sines, cosines, tangents, &c., being found in the columns at the *bottom* of which those terms are found. This arrangement is rendered practicable by the circumstance of the sines, tangents, &c., of angles being respectively equal to the cosines, cotangents, &c., of the complements of the same angle.

Besides the column headed sine, tangent, &c., are three smaller columns headed "Diff." They contain the difference between the values of the sines, cosines, &c., of consecutive logarithms corresponding to a change of 100″ in the arc; and it should be kept in mind that the same difference is common to the sine and cosecant, to the tangent and cotangent, and to the secant and cosine. They are inserted for the convenience of finding the values of the sines and cosines, &c., of angles which are expressed in degrees, minutes, and seconds.

In the use of these tables, as in that of the natural sines, two questions present themselves:—First, having given the angle in degrees, minutes, and seconds, required the log. sine, log. cosine, &c. Second, having given the log. sine, log. cosine, &c., required the value of the angle in degrees, minutes, and seconds.

If the angle whose logarithmic sine, tangent, &c., it is required to find, be given in degrees and minutes, look for the degrees, if the angle be less than 45°, at the top of the page, and for the minutes in the left hand column: if the angle be greater than 45°, look for the degrees at the bottom of the page, and for the minutes in the right hand column: the logarithm of the proposed function of the angle will be found opposite the numbers in its proper column.

Examples.

Log. sine of	40° 4′	is	9·808669		Log. sine of	57° 5′	is	9·924001
Log. cosine of	21 38	„	9·968278		Log. cosine of	79 51	„	9·246069
Log. tangent of	84 13	„	10·994466		Log. tangent of	21 50	„	9·602761
Log. cotangent of	55 58	„	9·829532		Log. cotangent of	27 45	„	10·278911
Log. secant of	70 20	„	10·472954		Log. secant of	44 59	„	0·150389
Log. cosecant of	8 35	„	10·826092		Log. cosecant of	69 54	„	0·027291

If the value of the angle be given in degrees, minutes, and seconds, we proceed by

Rule XVII.

1°. *Find from the table the sine, cosine, &c., which corresponds to the degrees and minutes.*

2°. *Multiply the tabular difference by the seconds, and divide by* 100.

3°. *If the required quantity be a sine, tangent, or secant,* add *the result to the last figures obtained in* 1°; *if it be a cosine, cotangent, or cosecant,* subtract. The result will be the required sine, cosine, &c.

Examples.

1. Find the log. sine of 6° 36′ 27″.

$$\begin{array}{lr} \text{Log. sine } 6^\circ\ 36' = & 9\cdot060460 \\ 27'' \text{ gives} & +\quad 491 \\ \hline & 9\cdot060951 \end{array} \qquad \begin{array}{lr} \text{Tab. diff.} & 1817 \\ & \times\ 27 \\ \hline & 12719 \\ & 3634 \\ \hline & 490{,}59 \\ \hline \text{or} & 491 \end{array}$$

Ans.: Log. sine 6° 36′ 27″ = 9·060951.

2. Find the log. cosine of 13° 5′ 32″.

$$\begin{array}{lr} \text{Log. cosine } 13^\circ\ 5' = & 9\cdot988578 \\ 32'' \text{ gives} & -\quad 16 \\ \hline & 9\cdot988562 \end{array} \qquad \begin{array}{lr} \text{Tab. diff.} & 50 \\ & \times\ 32 \\ \hline & 100 \\ & 150 \\ \hline & 16{,}00 \\ \hline \text{or} & 16 \end{array}$$

Ans.: Log. cosine 13° 5′ 32′ = 9·988562.

When the angle is greater than 90°, subtract it from 180°, and look for the remainder, which is called its *supplement*, in the tables.

Thus, to find the log. sine of 120° 24′, subtract it from 180°, and look for the log. sine of the remainder (namely 69° 36′), which is 9·971870; or log. sine 120° 24′ = 9·971870.

3. Find the log. tangent of 128° 55′ 47″.

Supplement of the given angle = 51° 4′ 13″.

$$\begin{array}{lr} \text{Log. tangent } 51^\circ\ 4' = & 0\cdot092664 \\ & +\quad 56 \\ \hline & 0\cdot092720 \end{array} \qquad \begin{array}{lr} \text{Tab. diff.} & 431 \\ & \times\ 13 \\ \hline & 1293 \\ & 431 \\ \hline & 56{,}03 \\ \hline \text{or} & 56 \end{array}$$

But a *readier* way will, in general, be to diminish the given angle by 90°, and to look out the remainder according to the following rule:—

Rule XVIII.*

If A *denote any angle less than* 90°, *then*

For sine	(90 + A)	*take out*......	*cosine* A
,, *tangent* ..	(90 + A)	——— ..	*cotangent* A
,, *secant*	(90 + A)	———	*cosecant* A
,, *cosine*	(90 + A)	———	*sine* A
,, *cosecant* ..	(90 + A)	———	*secant* A
,, *cotangent* ..	(90 + A)	———	*tangent* A

Thus, to find the log. cosine of 110°, or log. cosine (90 + 20), take out the log. sine 20°, which is 9·534052.

To find the log. secant of 160° 12′, take out the *co*secant 70° 12′, which is 10·026465.

Log. cosine of	143° 24′	=	Log. sine	53° 24′ is	9·904617
Log. cosecant of	99 37	=	Log. secant	9 37 ,,	0·006146
Log. sine of	109 2	=	Log. cosine	19 2 ,,	9·975583

Required the log. sine, tangent, secant, cosine, cotangent, and cosecant corresponding to the following arc:—

1.	6° 53′ 56″	7.	42° 50′ 32″	13.	37° 30′ 2″	19.	87° 28′ 45″	25.	112° 8′ 34″
2.	12 13 58	8.	48 35 35	14.	28 3 33	20.	75 52 39	26.	128 55$\frac{7}{8}$
3.	24 9 30	9.	56 54 17	15.	46 31 41	21.	115 34 41	27.	108 23 50
4.	37 49 14	10.	65 25 38	16.	70 47 40	22.	119 40 48	28.	163 43 19
5.	18 19 17	11.	10 10 6	17.	80 22 22	23.	176 6 20	29.	139 6 47
6.	32 40 18	12.	19 10 40	18.	82°·6791	24.	132 53 41	30.	124 54 17

If the value of the log. sine, log. cosine, &c., be given, and it is required to find the angle, we use

Rule XIX.

1°. *Find in the tables* (XXV, Norie) *the next lower*† *log. sine, log. cosine, &c., and note the corresponding degrees and minutes.*

2°. *Subtract this from the given log. sine, log. cosine, &c., multiply the difference by* 100, i.e., *annex two cyphers, divide by the tabular difference, and consider the result as seconds.*

---

* This rule may easily be remembered by observing that to the sine, tangent, and secant, *co* is prefixed, while from the *co*sine, *co*secant, and *co*tangent, the *co* is dropped, and in each case the excess above 90° of the angle is used.

† If the given log. be a cosine, cosecant, or cotangent, we may seek out the next *greater* to the given log.; then proceed by 2° to find the seconds, which *add* to the degrees and minutes as found by 1°.

3°. *If the given value be that of a log. sine, log tangent, or log. secant, add these seconds to the degrees and minutes found in 1°; if it be that of a log. cosine, log. tangent, or log. cosecant, subtract.*

The result will be the required angle.

EXAMPLES.

1. Given log. sine = 9·422195 (or $\bar{1}$·422195): find the angle.

Given log. sine 9·422195
Tab. log. sine next less 9·421857 = log. sine 15° 19′

Tab. diff. for 100″ = 768)·33800(44″ additional seconds
3072

3080
3072

Therefore 9·422195 = log. sine of 15° 19′ 44″.

2. Given log. cosine = 9·873242 (or $\bar{1}$·873242): find the angle.

Given log. cosine 9·873242
Tab. log. cosine next less 9·873223 = log. cosine 41° 41′

19

Tab. diff. = 187 $\frac{19 \times 100}{187}$ = 10″ *subtractive.*

Ans.: 41° 40′ 50″.

3. Given log. tangent $-\frac{86}{357}$: find the angle.

$-\frac{86}{357} = -$ ·240896, a negative mantissa = $\bar{1}$·759104, adding 10 to the index gives 9·759104 for the tabular log. tangent; and very nearly corresponding to this is found the angle 29° 52′.

Required the Angles (to the nearest second), the Log. Sine of which is:—

1.	9·741279	5.	8·600700	9.	9·929638	13.	$\bar{1}$·559234	16.	9·700000
2.	9·518317	6.	9·926100	10.	9·500000	14.	$\bar{1}$·422195	17.	8·846217
3.	9·693451	7.	9·903534	11.	9·800000	15.	Nt. s. $\frac{163}{308}$	18.	8·462167
4.	8·707654	8.	9·891164	12.	9·706176				

Find the Arc to the Log. Cosine of

1.	9·787140	3.	9·995637	5.	9·517232	7.	9·932338	9.	8·967391
2.	9·750333	4.	9·179726	6.	9·212036	8.	9·998970	10.	9·000000

Find the Arc to the Log. Secant of

1.	0·013839	3.	0·000765	5.	0·746129	7.	0·022716	9.	0·315400
2.	0·205665	4.	0·048398	6.	0·111777	8.	0·054304	10.	0·497691

Find the Arc to the Log. Cosecant of

1.	0·347194	4.	0·974476	7.	11·000873	10.	0·070362	13.	0·630000
2.	0·252208	5.	0·121000	8.	11·467931	11.	0·900000	14.	0·061462
3.	0·417357	6.	0·168600	9.	11·711010	12.	0·009000	15.	0·109761

Find the Arc to the Log. Tangent of

1.	0·636863	4.	0·536102	7.	11·276400	10.	8·297036	13.	9·846175
2.	0·000100	5.	0·150328	8.	9·609825	11.	9·642876	14.	0·060431
3.	0·827204	6.	0·060431	9.	0·198503	12.	0·846215	15.	$\frac{137}{488}$

Find the Arc to the Log. Cotangent of

1.	9·742691	4.	0·060431	7.	8·327691	10.	0·000276	13.	8·460000
2.	0·876432	5.	0·710880	8.	9·791422	11.	9·100100	14.	9·374611
3.	9·846175	6.	0·545104	9.	0·010101	12.	0·825001	15.	9·367736

NAVIGATION.

DEFINITIONS.

Navigation is a general term denoting that science which treats of the determination of the place of a ship on the sea, and which furnishes the knowledge requisite for taking a vessel from one place to another. The two fundamental problems of navigation are, therefore, the finding at sea the present position of the ship, and the determining the future course.

The place of a ship is determined by either of two methods, which are independent of each other:—1st. By referring it to some other place, as a fixed point of land, or a previous defined place of the ship herself. 2nd. By astronomical observations.

It has been customary to employ the term Navigation in a restricted sense to the first of these methods: the second is usually treated of under the head of Nautical Astronomy.

Navigation and Nautical Astronomy are the two great co-ordinate divisions of the "*Art of Sailing on the Sea,*" as the old writers quaintly worded it. The first branch of the art is accomplished by means of the Mariner's Compass, which shows the *direction* of the ship's track; the Log, which with the help of sand-glasses for measuring small intervals of time, gives the velocity or the rate of sailing, and thence the distance run in any interval, and also a Chart of appropriate construction; in short this branch of the art relates to the directing the ship's course under the varying forces of winds and currents, and the estimation of her change of place. The second division is that branch of practical astronomy by which the situation of the observer on the globe is ascertained by a *comparison of the position of his Zenith with relation to the heavens with the known position of the Zenith of a known place* at the same moment. The principal instruments are the sextant for measuring the altitudes and taking the distances of heavenly bodies; and a chronometer to tell us the difference in time between the meridian of the ship and the first meridian; also, a pre-calculated astronomical register, such as the Nautical Almanac, the Connaissance de Temps of France, &c. The solution of problems in nautical astronomy requires the use of spherical trigonometry, which is therefore characteristic of this method of navigation.

The earth is nearly a globe or sphere.

The ordinary proofs of this are of the following nature :—1st. When a vessel is seen at a considerable distance on the sea, in any part of the world, the hull is entirely or partly concealed by the water, though the masts are visible. 2nd. Ships have actually and repeatedly made the circuit of the globe; that is, by sailing from a port in a westerly direction they have returned to it in an easterly direction. 3rd. When we travel a considerable distance from north to south, a number of new stars appear, successively, in the heavens, in the quarter to which we are advancing, and many of those in the opposite quarter gradually disappear, which would not happen if the earth were a plane in that direction. 4th. In an eclipse of the moon, which is caused by the intervention of the body of the earth between the sun and moon, the shadow of the earth thrown on the moon is found in all cases, and in every position of the earth, to be a circular figure; the earth, therefore, which casts that shadow, must be a round body.

The earth, however, is not a perfect sphere, but of the figure of an oblate spheroid, being flattened in at the poles; that is, such a figure as would be produced if a hoop were slightly flattened by pressure, and then made to revolve about the shortest diameter thus produced.

The shortest diameter (that which joins the poles) being 7899 statute miles, and that of the fullest parts (about the equator) being nearly 26½ more.

We can, of course, in a work like this give no intelligible account of the refined mathematical processes by which the most probable values of the flattening in, and of the absolute dimensions have been obtained. It is sufficient to say, that from a combination of the measurements of ten arcs of the meridian, Bessel has deduced the following results :—

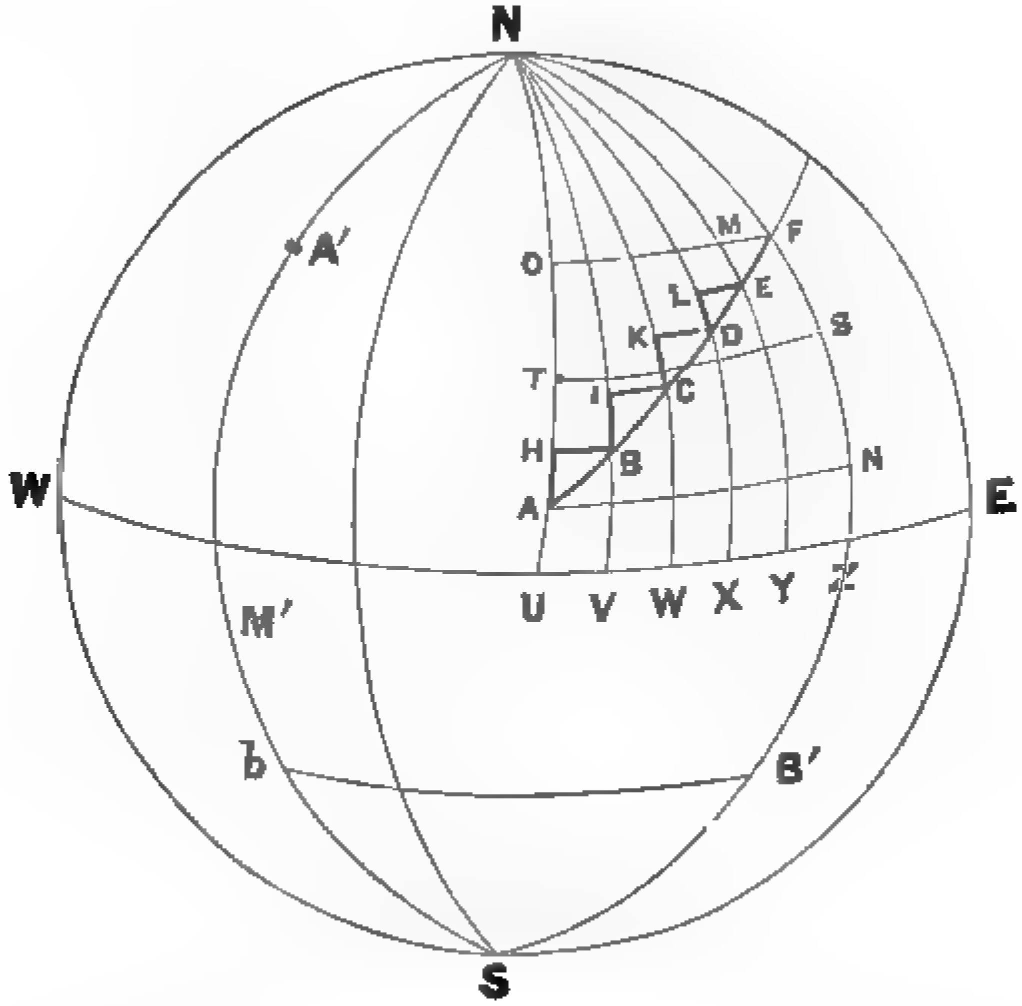
Greater, or equatorial diameter	41,847,192 feet	=	7925·604 miles.
Lesser, or polar diameter	41,707,324 „	=	7899·114 „
Difference of diameter, or polar compression .	139,768 „	=	26·471 „

Proportion of diameters, as 299·15 to 298·15.

And from the result it follows that the polar diameter is shorter than the equatorial by about $\frac{1}{300}$ (one-three hundredth) part. This quantity is technically called the *compression*.

With a view to our ascertaining our position on the surface of the globe, it is evidently necessary to settle some fixed points or lines to which we may refer various places, and by which we may express their positions, and also frame directions for sailing over its surface. With a view to these objects, certain lines are imagined to be traced on the surface of the earth; and on the artificial globe, on which the prominent features of this surface are depicted, the imaginary lines alluded to are certainly drawn. Their definitions, with those of certain remarkable points, are as follows :—

THE AXIS OF THE EARTH is one its diameters about which it is supposed to turn round once in twenty-four hours. The direction of this rotation is from west to east, thus causing all the heavenly bodies to have an apparent motion from east to west.



POLES.—The extremities of the axis of the earth about which it rotates are called the *poles* of the earth, distinguished respectively as the *North Pole* and *South Pole*—as N. S. (see fig.) The former being that to which we in Europe are nearest. As they are the extremities of a diameter they are 180° apart.

EQUATOR (from Latin *æquare* to divide into equal parts), called also by seamen the Line, is a great* circle circumscribing the earth, every point of which is equally distant from both poles, as W. M'. E.; and dividing the globe into two equal parts, called hemispheres; that

* By a *great* circle is meant a circle of the sphere having for its centre, the centre of the sphere, thus dividing the sphere into two equal parts: no greater circle can be traced upon its surface. All other circles are called *small* circles

towards the north pole is called the northern hemisphere, as N. W. E., and the other the southern hemisphere, as S. W. E. (See figure, page 44).

At all places on this circle the sun rises at 6^h A.M. and sets at 6^h P.M., all the year round; the days and nights are therefore equal, being 12^h each.

THE MERIDIAN of any place is a semi-circle passing through that place and the poles, as N. M′. S. (See figure). Every point on the surface of the earth may be conceived to have a meridian passing through it; hence there may be as many meridians as there are points in the equator. Of all these innumerable meridians one is always selected as the principal or *first meridian*; it is a matter of arbitrary choice amongst different nations; thus the first meridian with us is that of Greenwich, whilst the French refer to Paris, &c.

Every portion of the meridian lies north and south; and places lying north and south of each other are said to be on the same meridian.

The direction of the meridian towards the north pole is called *north*, and marked N; the opposite direction is called *south*, marked S. Directions at right angles to the meridians are called *east* and *west*; the right hand looking to the north *east*, the left hand *west*: they are marked E. and W.

Every meridian line may be said, with respect to the place through which it passes, to divide the surface of the sphere into two equal parts called the eastern and western hemispheres.

Meridians (*L. Meridies*, from *medius dies* mid-day) are so called because they mark all places which have noon at the same instant, for when any one of the meridians is exactly opposite the sun it is mid-day with all places situated on that meridian; and with the places situated on the opposite meridian it is consequently midnight. They also mark out all places which have the same longitude, and are hence called "*Circles of Longitude.*"

LATITUDE is the distance of a place from the equator, measured in degrees (°), minutes (′), and seconds (″),* on the meridian of the place, or it is that portion of the meridian of a place, included between the place and the equator; it is marked *north* (N.), or *south* (S.), according as the place is to the north or south of the equator. Thus, A′ M′, (fig., page 44) is the latitude of a place A′, and is marked N., because A′ is to the north of W. M′. E.: whilst the latitude of B′ is M′ B′, and is marked S., because the place B′ is to the south of the equator.

* All circles are supposed to be divided into 360 equal parts called degrees (°). 60′ (minutes) make one degree, and 60″ (seconds) make one minute.

As the latitude begins at the equator (lat. 0°), and is reckoned thence to the poles, (latitude 90°,) all other places must have their latitude intermediate between 0° and 90°.

Parallels of Latitude are small circles of the sphere parallel to the equator; they mark all places on the earth, which have the same latitude; and all places of the same latitude being at the same distance from the equator, are said to be on the same parallel: thus (fig., page 44), O, F, and *b* B′, are parallels of latitude, and all places on O, F, and *b* B′, &c., have the same latitude, being on the same parallel.

The Difference of Latitude (abbreviated *diff. lat.*) between two places is the arc of a meridian included between their parallels of latitude, shewing how far one of them is to the northward or southward of the other; thus (fig. p. 44) A′ *b* is the difference of latitude of the two places A′ B′; F S between the places F T. The difference of latitude between two places can never exceed 180°.

It is evident, that when two places are on the *same* side of the equator, their diff. lat. is found by subtracting the lesser latitude from the greater; and that when they are on *opposite* sides of the equator, that is, when one place is in north latitude and the other in south latitude, the *sum* of their latitudes is the diff. lat. Thus, the diff. of lat. of A′ B′ which is A′ *b*, is the sum of the north lat. A′ M′, and of the south lat. Z B′ or M′ B′.

The difference of latitude of the ship is therefore the distance made good in a north or south direction. This is also called her "*northing*" or "*southing*," these names being indicated by their initials N. or S.

Meridional Parts.—At the equator a degree of longitude is equal to a degree of latitude, but as we approach the poles, while (upon the supposition that the earth is a sphere) the degrees of latitude remain the same, the degrees of longitude become less and less. In the chart, on Mercator's projection, the degrees of longitude are made everywhere of the same length, and, therefore, to preserve the proportion that exists at different parts of the earth's surface between the degrees of latitude and the degrees of longitude, the former must be increased from their natural lengths, more and more as we recede from the equator. The lengths of small portions of the meridian thus increased, expressed in minutes of the equator, are called meridional parts; and the *meridional parts for any latitude* is the line, expressed in minutes of the equator,

into which the latitude is thus expanded. The meridional parts computed for every minute of latitude from 0° to 90°, from the *table of meridional parts*, which is chiefly used for finding the meridional difference of latitude in solving problems in Mercator's sailing, and for constructing charts on Mercator's projection.

THE MERIDIONAL DIFFERENCE OF LATITUDE is the quantity which bears the same ratio to the difference of latitude that the difference of longitude bears to the departure. It is the projection of the difference of latitude on the Mercator's chart, and takes its name from the meridional parts by the use of a table of which it is found.

MIDDLE LATITUDE.—When the two places are situated on the *same* side of the equator, the middle latitude is the latitude of the parallel passing midway between them; its value is therefore half the sum of the latitudes of the two places. When the two places are situated in *opposite* sides of the equator, the simple "middle latitude" is replaced by the two half latitudes of each of the places. (See Raper's Navigation, page 98.)

LONGITUDE is the arc of the equator, intercepted between the meridian of the place and the first meridian; and it is named east (E.), or west (W.), according as it is east or west of the first meridian.

Longitude is reckoned from the meridian of Greenwich both east and west as far as 180°.

It will be evident that the latitude alone will be insufficient for the determination of the position of a place. If we state that a certain place is 45° north of the equator, it will be impossible to ascertain certainly the place in question, inasmuch as there is a circle of points on the earth, all of which are 45° north of the equator. If we suppose a circle drawn round the surface of the northern hemisphere parallel to the equator, at the distance from the equator of 45°, every point of such circle will be equally characterized by the latitude of 45°. But if we state its latitude and longitude, we can fix at once and unequivocally, the position of the place. Thus, let us suppose that its latitude is 50° north, its longitude 30° east of Greenwich; its position will be found by imagining a circle parallel to the equator, drawn upon the northern hemisphere at a distance of 50° from the equator; then supposing a meridian drawn through Greenwich intersecting this parallel, and another drawn so as to cross the equator at a point 30° east of the former; the place in question will be upon the line parallel to the equator first drawn, inasmuch as it will be 50° north of the equator, and it will also be in the meridian last drawn, inasmuch as it will be 30° east of Greenwich. Since, then, it will be at the same time upon both these lines, it will necessarily be at the point where they cross each other at the east of the standard meridian of Greenwich.

DIFFERENCE OF LONGITUDE between two places is the arc or portion of the equator included between their meridians, or, which is the same

thing, the corresponding angle at the pole; thus M′ W is the difference of longitude between A′ and H. To measure, therefore, the diff. of longitude of two places, we must follow down their meridians to the equator, and then take the included portion of the equator itself.

THE COURSE is the direction in which a ship sails from one place to another, this direction being referred to the meridian, which lies truly north and south, or to the position of the magnetic needle by which the ship is steered. The former is distinguished as the *True Course*, the latter as the *Compass Course*. The *course steered* is also distinguished from the course made good, which is the angle between the meridian and the ship's head.

The course is reckoned from the north towards the east or west, when the ship's head is less than eight points from the north; and similarly from the south point.

The course is measured in *points* of 11° 15′ each, or in degrees and minutes.

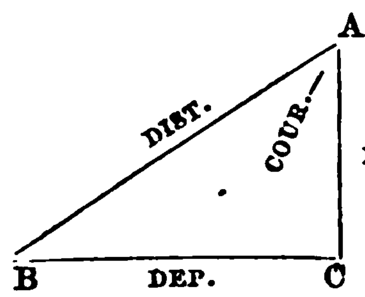
When a ship in sailing from one place to another, preserves the same angle with the meridians, as she crosses them in succession, she is said to sail on a RHUMB LINE. Thus, a ship in sailing from A to F (fig. page 44) is supposed to describe on the sea a curve A F, which cuts the meridians N A F, N B F, N C F, &c., at the same angle; that is, the angles N A F, N B F, N C F, are supposed to be equal. The rhumb line coincides with the meridian when the course is due N. or S., or with a parallel of latitude when the course is due E. or W. On any other course but these the rhumb line is a spiral, approaching nearer and nearer to one of the poles at every convolution.

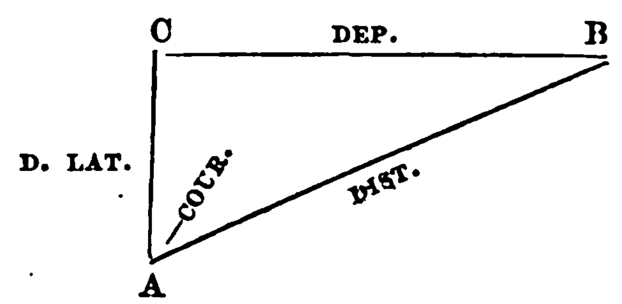
The word rhumb was formerly applied to the points of the compass, and having to sail on a "rhumb," was to sail on a particular compass direction. The rhumb line is also called the "*Equiangular Spiral*," and the "*Loxodromic Curve*." It is the track used ordinarily in navigation, for when out of sight of land the compass determines the ship's track, and hence the selection of that track which makes a constant angle with the meridian, the advantage of such a selection being that the seaman is not required to alter his course. When in sight of his port the compass is no longer needed, and the rhumb line is given up, and the port is made for on the great circle. When accurately following the compass course, we are, in strictness, only approximating, though very closely approximating, to a rhumb line, on account of the continuous change in the variation due to the magnetic pole and the pole of the earth not being coincident.

The Distance between two places is the arc of the rhumb line joining them, expressed in nautical miles, of 60 to the degree of latitude. Thus, the length of line A F expressed in minutes of a great circle of the earth, is called the *distance*.*

It is *not* the *shortest* distance, that is the distance as the "crow flies." On a Mercator's Chart the rhumb is represented by a straight line, but it must be borne in mind that equal parts of any such line do not represent equal distances on the earth.

Departure is the distance, in nautical miles, made good due east or due west, and is marked east (E.), or west (W.), according as it is made good towards the east or west. In the former case it is called "easting," in the latter "westing," and such departure is expressed in *miles*, and not like the longitude, in *arc*. Thus, if a ship sails from a place A to another B, A B is the *distance;* A C drawn N. and S., or in the meridian, shows the angle C A B the *course;* B C drawn E. and W., or perpendicular to C A, is the *departure;* and A C is the *diff. of lat.*





If a ship's course be due north or south, she sails on a meridian, and therefore makes no departure:—hence the distance sailed will be equal to the difference of latitude.

If a ship sails either due east or due west, she sails on a parallel of latitude; in which case she makes *no difference of latitude*, and the departure is identical with the distance.

When the course is 4 points, or 45 degrees, the difference of latitude and departure are equal.

When the course is *less* than 4 points, or 45 degrees, the difference of latitude exceeds the departure; but when it is *more* than 4 points, or 45 degrees, the departure exceeds the difference of latitude.

The Bearing of an object or place is the angle contained between the meridian and the direction of the object, and is the same thing as the course towards it. Taking a bearing of an object is called *setting* it.

* Minutes of a great circle are usually called *nautical miles*, or simply miles.

PRELIMINARY RULES IN NAVIGATION.

Given the latitude from and latitude in or to, *to find the true difference of latitude.*

RULE XX.

To find the difference of latitude. (For definition, see pages 45 and 46.)

1st. When the latitudes have *like* names—*Subtract the less latitude from the greater, and multiply the degrees in the remainder by* 60, *adding in the minutes; place* N. *or* S. *against the result, according as the lat.* to *is North or South of the lat.* from. The result is the true difference of latitude.

2nd. When the latitudes have *unlike* names—*Take the sum of the two latitudes, reduce it to minutes, and attach* N. *or* S. *according as the lat.* to *is* N. *or* S. *of lat.* from. The result is the true difference of latitude.

Examples.

Ex. 1. Find the diff. of lat. between Tynemouth Light, in lat. 55° 1′ N., and the Naze of Norway, in lat. 57° 58′ N.

Lat. Tynemouth	55° 1′	N.
Lat. Naze	57 58	N.
	2 57	
	60	
D. lat.	177	N.

The lat. *from* (Tynemouth) and lat. *to* (Naze) being of the *same name*, that is, both North, the difference of them is taken for the diff. lat., and since we have to pass from a lower North lat. to a higher, the diff. lat. is marked North (N.)

Ex. 2. Required the diff. of lat. between Cape Formosa, in lat. 4° 15′ N., and St. Helena, in lat. 15° 55′ S.

Lat. C. Formosa	4° 15′	N.
Lat. St. Helena	15 55	S.
	20 10	
	60	
D. lat.	1210	S.

The lat. *from* (C. Formosa) is *North*, and the lat. *to* (St. Helena) is *South*, it is evident that the ship must sail South in order to pass from North lat. into South; whence we put South (S.) to the diff. of lat.

Ex. 3. A ship from lat. 32° 40′ N. sails into lat. 20° 47′ N: what is the diff. of lat. made?

Lat. from	32° 40′	N.
Lat. to	20 47	N.
	11 53	
	60	
	713	S.

The ship here passes from a *higher* N. lat. to a *lower* N. lat., and to do so must evidently sail S.; whence we mark d. lat. S.

Ex. 4. Required the diff. of lat. between Port Natal, in lat. 29° 53′ S., and Akyab, in lat. 20° 8′ N.

Lat. Port Natal	29° 53′	S.
Lat. Akyab	20 8	N.
	50 1	
	60	
	3001	N.

As the ship (Port Natal) is S. hemisphere and Akyab is the N. hemisphere, to pass from the former into the latter the ship must sail N.

Ex. 5. A ship from lat. 50° S. arrives in lat. 45° 29′ S.: what is the diff. of lat.

Lat. from	50° 0′	S.
Lat. in	45 29	S.
	4 31	
	60	
	271	N.

Here the ship passes from a *higher* to a *lower* S. lat., and to do so must evidently sail N.; whence the d. lat. is marked N.

Ex. 6. A ship from lat. 13° 45′ S., arrives in lat. 26° 15′ S.: Required d. lat.

Lat. from	13° 45′	S.
Lat. in	26 15	S.
	12 30	
	60	
	750	S.

Here the ship passes from a *lower* to a *higher* S. lat., and to do so must evidently sail S.; whence S. is marked against d. lat.

Ex. 7. A ship from lat. 23° 48′ S. is bound to a port in lat. 31° 12′ N.: what d. lat. will she make.

Lat. from	23° 48′	S.
Lat. to	31 12	N.
	55 0	
	60	
D. lat.	3300	N.

Ex. 8. A ship from a place A, in lat. 54° 39′ N., is bound to a place B, in lat. 46° 21′ S.: required the d. lat.

Lat. A	54° 39′	N.
Lat. B	46 21	S.
	101 0	
	60	
D. lat.	6060	S.

When one of the places has no latitude, or is on the Equator, the latitude of the other place is the difference of latitude.

Ex. 9. A ship from a place A, is lat. 10° N., arrives at a place B, in lat. 0°: required the D. lat. made.

Lat. A	10°	N.
Lat. B	0	
	10	
	60	
D. lat.	600	S.

Ex. 10. A ship from a place A, lat. 0°, is bound to a place B, lat. 25° S: Required the D. lat.

Lat. A	0°	
Lat. B	25	S.
	25	
	60	
D. lat.	1500	S.

Since lat. is reckoned from the Equator lat. 0° (N. or S.) to pass from 0° to 25° S., the ship must evidently sail S; whence the d. lat. is marked S.

Required the difference of latitude between the place A and the place B in each of the following examples:

1.	Lat. A 55° 0′ N.	2.	Lat. A 50° 38′ N.	3.	Lat. A 20° 36′ S.
	B 58 23 N.		B 42 48 N.		B 18 48 N.
4.	Lat. A 58° 24′ S.	5.	Lat. A 4° 21′ N.	6.	Lat. A 3° 42 S.
	B 63 17 S.		B 5 39 S.		B 1 48 N.
7.	Lat. A 13° 15′ S.	8.	Lat. A 0° 0′	9.	Lat. A 10° 10′ N.
	B 0 0		B 2 37 S.		B 0 0
10.	Lat. A 0° 0′	11.	Lat. A 0° 17′ S.	12.	Lat. A 49° 58′ N.
	B 20 30 N.		B 1 17 N.		B 36 7 N.
13.	Lat. A 49° 52′ S.	14.	Lat. A 15° 53′ S.	15.	Lat. A 65° 42′ N.
	B 42 13 S.		B 23 55 S.		B 70 30 N.

To find the meridional difference of latitude, having given the latitude from and latitude in.

RULE XXI.

To find the meridional difference of latitude. (For definition, see pages 46 and 47.)

Take the meridional parts for the two latitudes from the table of meridional parts; take the difference *if the latitudes are of the same name, but their* sum *if the names are* unlike. The result is the meridional difference of lat.

EXAMPLES.

Ex. 1. Lat. A 49° 10′ N., lat. B 27° 40′ N.: find the mer. diff. of lat.

Lat. A	49° 10′ N.	M. parts	3397
B	27 40 N.	„	1729
		Mer. d. lat.	1668

Ex. 2. Lat. left 49° 58′ N., and lat. bound to 32° 42′ N.: find mer. diff. lat.

Lat. left	49° 58′ N.	M. parts	3471
Lat. to	32 42 N.	„	2078
		Mer. d. lat.	1393

Ex. 3. Lat. left 29° 53′ S., and lat. to 20° 8′ N.: required mer. diff. lat.

Lat left	29° 53′ S.	Mer. parts	1880
Lat. to	20 8 N.	„	1234
		Mer. d. lat.	3114

Ex. 4. Lat. from 46° 40′ N., and lat. to 34° 22′ S.: find the mer. d. lat.

Lat. left	46° 40′ N.	Mer. parts	3173
Lat. to	34 22 S.	„	2198
		Mer. d. lat.	5371

Ex. 5. Lat. from 36° 57′ N., and lat. to 49° 58′ N.: required the mer. diff. lat.

Lat. from	36° 57′ N.	M. parts	2389
Lat. to	49 58 N.	„	3471
		Mer. d. lat.	1082

Ex. 6. Lat. from 8° 57′ N., and lat. to 36° 50′ S.: required mer. diff. lat.

Lat. from	8° 57′ N.	M. parts	539
Lat. to	36 50 S.	„	2380
		Mer. d. lat.	2919

Find the meridional difference of latitude in each of the following examples :—

1.	Lat. from 34° 40′ N.	Lat. in	33° 20′ N.	7.	Lat. from 8° 4′ S.	Lat. in	14° 45′ N.
2.	„ 14 14 N.	„	30 14 N.	8.	„ 15 44 S.	„	4 20 N.
3.	„ 24 12 S.	„	15 18 N.	9.	„ 15 55 S.	„	23 56 S.
4.	„ 49 10 S.	„	52 47 S.	10.	„ 9 6 N.	„	18 54 N.
5.	„ 40 15 N.	„	41 25 N.	11.	„ 60 20 S.	„	67 10 S.
6.	„ 50 42 S.	„	42 17 S.	12.	„ 0 0	„	4 20 N.

To find the latitude in, having given the latitude from and true difference of latitude.

RULE XXII.

1°. When latitude and true difference of latitude have *like* names—*To the latitude from* add *the true difference of latitude (turned into degrees, minutes, and seconds, if necessary); the* sum *will be the* latitude in, *of the* same *name as the* latitude from.

2°. When the latitude from and true difference of latitude have *unlike* names—*Under the latitude* from, *put the true difference of latitude (in degrees and minutes, if necessary); the* remainder *marked with the name of the* greater *is the* latitude in.

Examples.

Ex. 1. A ship from lat. 59° 27′ S., sails South, until the diff. lat. is 374 miles: required the lat. come to.

6,0)37,4	Lat. from	59° 27′ S.
6° 14′ S.	D. lat.	6 14 S.
	Lat. in	65 41 S.

Ex. 2. A ship from lat. 2° 25′ N. sails South, 180 miles: what lat. is she in?

6,0)18,0	Lat. from	2° 25′ N.
3° 0′	D. lat.	3 0 S.
		0 35 S.

In this example it is evident that as the d. lat. is more than the lat. left, the ship must have crossed the Equator, and consequently has come into South lat.

Ex. 3. A ship from lat. 55° 1′ N. sails North, 94 miles; find the lat. in.

6,0)9,4	Lat. from	55° 1′ N.
1° 34′	D. lat.	1 34 N.
	Lat. in	56 35 N.

Ex. 4. A ship from lat. 28° 39′ N. sails South, 131 miles: required the lat. in.

6,0)13,1	Lat. from	28° 39′ N.
2° 11′	D. lat.	2 11 S.
	Lat. in	26 28 N.

Ex. 5. A ship from lat. 0° 49′ S. sails North, 83 miles: required the lat. in.

6,0)8,3	Lat. from	0° 49′ S.
1° 23′	D. lat.	1 23 N.
	Lat. in	0 34 N.

Ex. 6. A ship from lat. 3° 12′ N. sails South 192 miles: required the lat. arrived at.

6,0)19,2	Lat. from	3° 12′ N.
3° 12′ S.	D. lat.	3 12 S.
	On the Equator	0 0

Find the latitude in, in each of the following examples:—

1.	Lat. from 31° 10′ N.	D. lat. 172 N.		9.	Lat. from 0° 8′ N.	D. lat. 182 S.
2.	„ 29 38 N.	„ 104 S.		10.	„ 0 39 N.	„ 59 S.
3.	„ 3 2 S.	„ 190 N.		11.	„ 3 58 N.	„ 238 S.
4.	„ 50 31 S.	„ 189 N.		12.	„ 1 27 S.	„ 102 N.
5.	„ 2 56 S.	„ 357 N.		13.	„ 4 48 S.	„ 288 N.
6.	„ 49 5 N.	„ 164 S.		14.	„ 35 25 S.	„ 229 S.
7.	„ 0 0	„ 168 S.		15.	„ 1 6 N.	„ 66 S.
8.	„ 38 41 S.	„ 110 N.		16.	„ 2 49 S.	„ 243 N.

To find the middle latitude, having given the latitude from and latitude in. (For definition, see page 47.)

RULE XXIII.

The names being supposed *alike*, that is, both *North* or both *South*—*Add together the true latitudes, and* take *half the sum; the result is the middle latitude.*

NOTE.—When the names are unlike, the middle latitude (which is seldom required, but for obtaining the departure) should be found by means of a table; but in this case, it may perhaps be as well to avoid the use of the middle latitude in any of the common problems of navigation.

EXAMPLES.

Ex. 1. Find the mid. lat., having given the lat. from 50° 25′ N., and lat. in 47° 12′ N.

Lat. from	50°	25′	N.
Lat. in	47	12	N.
	2)97	37	
Mid. lat.	48	48	

Ex. 2. Lat. from 6° 28′ S., lat. in 14° 50′ S.: required the mid. lat.

Lat. from	6°	28′	S.
Lat. in	14	50	S.
	2)21	18	
Mid. lat.	10	39	

Ex. 3. Lat. left 60° 52′ N., diff. lat. 143′ N.: required mid. lat.

6,0)14,3

2° 23′ N.

Lat. from	60°	52′	N.
D. lat.	2	23	N.
Lat. in	63	15	N.
Sum of lats.	124	7	
Mid. lat.	62	3½	

Ex. 4. Lat. left 40° 30′ S., diff. lat. 73′·4 N.: required mid. lat.

6,0)7,3

1° 13′ N.

Lat. from	40°	30′	S.
D. lat.	1	13	N.
Lat. in	39	17	S.
Sum of lats.	79	47	
Mid. lat.	39	53½	

Required the middle latitude in each of the following examples.

1.	Lat. from 16° 10′ S.	D. lat. 138′ S.	6.	Lat. A 63° 53′ S.	Lat. B 59° 10′ S
2.	„ 27 48 S.	„ 128 N.	7.	„ 56 10 N.	„ 50 15 N.
3.	„ 1 40 S.	„ 61 S.	8.	„ 37 36 N.	„ 24 15 N.
4.	„ 36 22 N.	„ 90 S.	9.	„ 67 20 S.	„ 61 42 N.
5.	„ 50 22 N.	„ 169 N.	10.	„ 8 52 N.	„ 4 52 N.

To find the difference of longitude, having given the longitude from and the longitude to.

RULE XXIV.

To find the difference of longitude. (For definition, see page 47.)

1st. When the longitudes are of the *same* name—*Take their difference and reduce the same to minutes, place* E. *or* W. *against the remainder, according as the long.* to *is East or West of long.* from.

2nd. When the longitudes are of *contrary* names—*Take the sum of the two longs., and attach* E. *or* W., *according as the long.* to *is East or West of long.* from.

Note.—If the difference of longitude found by the preceding rule exceeds 180°, subtract it from 360°, and reduce the remainder thus found to minutes, attaching to it the contrary name to that found in the usual way.

Ex. 1. Find the diff. of long., having given the long. from 89° 42′ W., and long. in 79° 42′ W.

Long. from	89°	42′	W.
Long. in	79	42	W.
	10	0	
	60		
D. long.	600		E.

Ex. 2. Required the diff. of long., having given the long. from 12° 20′ E., and long. in 2° 45′ W.

Long. from	12°	20′	E.
Long in.	2	45	W.
	15	5	
	60		
D. long.	905		W.

Ex. 3. A ship from Cape Bajoli, long. 3° 48′ E., is bound to Cape Sicie, in long. 5° 51′ E.: required the diff. of long.

Long. Cape Bajoli	3°	48′	E.
Long. Cape Sicie	5	51	E.
	2	3	
	60		
D. long.	123		E.

Ex. 4. A ship from Tynemouth, in long. 1° 25′ W., is bound to long. 7° 12′ E. required the diff. of long.

Long. from	1°	25′	W.
Long. to	7	12	E.
	8	37	
	60		
D. long.	517		E.

Ex. 5. A ship from long. 177° 50′ E. arrives in long. 178° 10′ W.: what diff. of long. has she made?

Long. left	177°	50′	E.
Long. in	178	10	W.
	356	0	
	360	0	
	4	0	
	60		
D. long.	240		E.

Ex. 6. From long. 178° 50′ W. a ship arrives in long. 108° 20′ E.: what diff. long. has she made?

Long. from	178°	50′	W.
Long. to	108	20	E.
	287	10	
	360	0	
	72	50	
	60		
D. long.	4370		W.

Ex. 7. A ship from long. 5° 12′ W. is bound to a port in long. 90° W.: what diff. of long. must she have made?

Long. from	5°	12′	W.
Long. to	90	0	W.
	84	48	
	60		
D. long.	5088		E.

Ex. 8. A ship from long. 165° E. is bound to a place in long. 72° 12′ E.: what diff. of long. must she have made?

Long. left	165°	0	E.
Long. to	72	12	E.
	92	48	
	60		
D. long.	5568		W.

Required the difference of longitude between a place A and a place B, in each of the following examples:—

1.	Long. A	9° 29′ W.	Long. B	4° 29′ W.	11.	Long. A	40° 10′ E. Long. B 33° 10′ E.
2.	"	3 48 E.	"	5 51 E.	12.	"	178 30 W. " 178 30 E.
3.	"	1 25 W.	"	7 2 E.	13.	"	43 9 W. " 18 29 E.
4.	"	6 11 E.	"	5 45 W.	14.	"	176 34 E. " 176 34 W.
5.	"	0 0	"	4 20 W.	15.	"	104 0 W. " 110 30 W.
6.	"	4 20 W.	"	0 10 E.	16.	"	38 32 W. " 8 43 E.
7.	"	2 45 W.	"	3 30 E.	17.	"	18 29 E. " 5 43 W.
8.	"	3 15 W.	"	3 15 E.	18.	"	161 10 W. " 180 0 W.
9.	"	7 2 E.	"	0 0	19.	"	122 22 W. " 111 11 E.
10.	"	0 55 E.	"	7 3 E.	20.	"	5 12 W. " 25 12 W.

To find the longitude in, having given the longitude from and the difference of longitude.

RULE XXV.

1°. When the longitude from and the difference of longitude have *like* names—*To the longitude from,* add *difference of longitude (turned into degrees, if necessary); the* sum *will be the* longitude in *of the* same *name as the* longitude from.

2°. When the longitude left and difference of longitude have *unlike* names—*Under* longitude from, *put difference of longitude (in degrees and minutes, if necessary); take the* less *from the* greater; *the* remainder, *marked with the name of the* greater, *is the* longitude in.

NOTE.—If the longitude in, found as above, exceed 180°, subtract it from 360°, and attach to the remainder the contrary names to the one directed in the Rule.

Ex. 1. A ship from long. 5° 12′ W. makes diff. long. 113′ W.: required the long. in.

	Long. from	5° 12′ W.
6,0)11,3	D. long	1 53 W.
1° 53′ W.	Long. in	7 5 W.

Ex. 2. A ship from long. 1° 25′ W. sails E. until her diff. of long. is 177′: required her long. in.

	Long. from	1° 25′ W.
6,0)17,7	D. long.	2 57 E.
2° 57′ E.	Long. in	1 32 E.

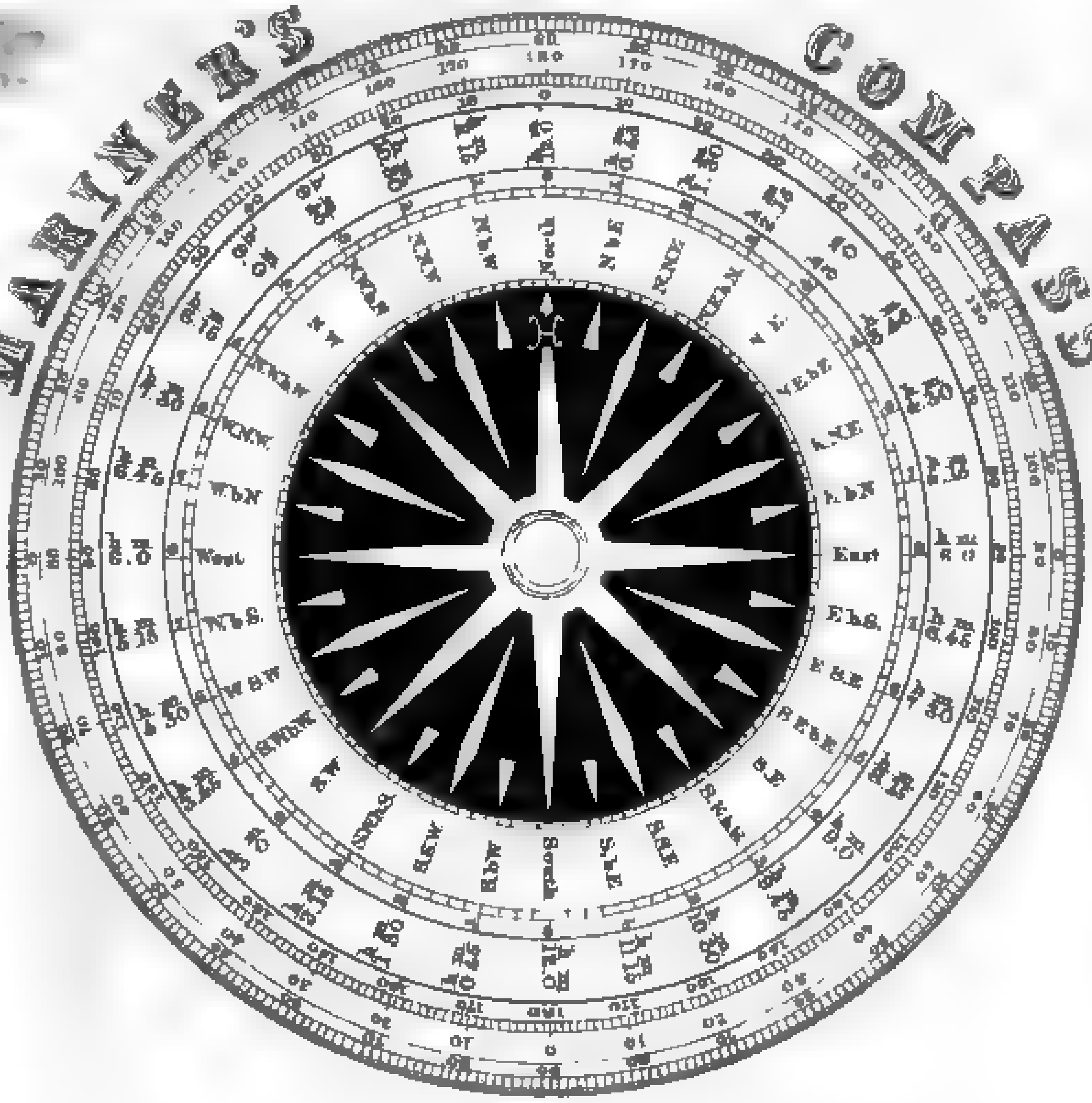
Ex. 3. A ship from long. 0° 57′ E. sails W. until her diff. of long. is 201′: find the long. in.

	Long. from	0° 57′ E.
6,0)20,1	D. long.	3 21 W.
3° 21′ W.	Long. in	2 24 W.

Ex. 4. Let the long. left be 174° 4′ W. and the diff. of long. 797′ W.: required the long. in.

	Long. from	174° 4′ W.
6,0)79,7	D. long.	13 17 W.
13° 17′ W.	Sum	187 21 W.
		360 0
	Long. in	172 39 E.

MARINER'S COMPASS



A TABLE OF THE ANGLES

which every Point & Quarter Point of the Compass makes with the Meridian

NORTH		POINTS		° ′ ″	POINTS		SOUTH	
		0	¼	2 48 45	0	¼		
		0	½	5 37 30	0	½		
		0	¾	8 26 15	0	¾		
N.b.E.	N.b.W.	1		11 15 0	1		S.b.E.	S.b.W.
		1	¼	14 3 45	1	¼		
		1	½	16 52 30	1	½		
		1	¾	19 41 15	1	¾		
N.N.E.	N.N.W.	2		22 30 0	2		S.S.E.	S.S.W.
		2	¼	25 18 45	2	¼		
		2	½	28 7 30	2	½		
		2	¾	30 56 15	2	¾		
N.E.b.N.	N.W.b.N.	3		33 45 0	3		S.E.b.S.	S.W.b.S.
		3	¼	36 33 45	3	¼		
		3	½	39 22 30	3	½		
		3	¾	42 11 15	3	¾		
N.E.	N.W.	4		45 0 0	4		S.E.	S.W.
		4	¼	47 48 45	4	¼		
		4	½	50 37 30	4	½		
		4	¾	53 26 15	4	¾		
N.E.b.E.	N.W.b.W.	5		56 15 0	5		S.E.b.E.	S.W.b.W.
		5	¼	59 3 45	5	¼		
		5	½	61 52 30	5	½		
		5	¾	64 41 15	5	¾		
E.N.E.	W.N.W.	6		67 30 0	6		E.S.E.	W.S.W.
		6	¼	70 18 45	6	¼		
		6	½	73 7 30	6	½		
		6	¾	75 56 15	6	¾		
E.b.N.	W.b.N.	7		78 45 0	7		E.b.S.	W.b.S.
		7	¼	81 33 45	7	¼		
		7	½	84 22 30	7	½		
		7	¾	87 11 15	7	¾		
East	West	8		90 0 0	8		East	West.

M & M W Lambert Newcastle

Ex. 5. Long. from 3° 40′ W., diff. of long. 220′ E.: required the long. in.

	Long. from	3° 40′ W.
6,0)22,0	D. long.	3 40 E.
3° 40′ E.	Long. in	0 0

On the Meridian of Greenwich.

Ex. 6. A ship from long. 177° 40′ W. makes 140′ diff. of long. to the W.: required the long. arrived at.

	Long. from	177° 40′ W.
6,0)14,0	D. long.	2 20 W.
2° 20′ W.	Long. in	180 0 W.
	Or	180 0 E.

Required the longitude in, or arrived at, in each of the following examples:—

1.	Long. from	5° 48′ W.	D. long	110′ W.
2.	"	0 59 W.	"	137 E.
3.	"	29 10 E.	"	114 E.
4.	"	3 10 E.	"	220 W.
5.	"	2 47 W.	"	242 E.
6.	"	3 18 E.	"	198 W.
7.	"	0 0	"	100 W.
8.	"	3 12 E.	"	237 W.
9.	"	2 30 E.	"	127 E.
10.	Long. from	41° 29′ W.	D. long.	139′ E.
11.	"	27 56 W.	"	74 W.
12.	"	94 4 E.	"	115 W.
13.	"	98 54 E.	"	302 E.
14.	"	178 13 E.	"	201 E.
15.	"	177 6 W.	"	237 W.
16.	"	176 20 E.	"	220 E.
17.	"	179 8 E.	"	193 E.
18.	"	179 59 W.	"	2 W.

CORRECTING COURSES.

The corrections of the compass are those quantities which must be applied to the indications of the instrument to obtain the reading that would be given if the north point of the compass-card always corresponded to the north point of the horizon. Three corrections are sometimes necessary to be applied to the course steered by compass, to reduce it to the true course; and the converse. These are called

1. The Leeway.
2. The Variation of the Compass.
3. The Deviation of the Compass.

1. LEEWAY.

The angle included between the direction of the fore-and-aft line of a ship, and that in which she moves through the water, is called the *leeway*. When the ship is not going before the wind she will not only be forced forward in the direction of her head, but, in consequence of the wind pressing against her sideways, her actual course will be to

leeward of the apparent course she is lying. The amount of leeway *differs* in different ships; depending on their construction, on the sails set, the velocity forward, and other circumstances. Experience and observation are required to judge what amount of leeway to allow in each case. The correction for *leeway* is necessary to deduce the course made good from the course steered, and it is one of the corrections to be applied in reducing the compass course to the true course in the day's work; the correction being allowed according to

RULE XXVI.

When the ship is on the port tack, *allow the leeway to the* right *of the course steered; but when on the* starboard tack, *allow it to the* left, *the observer looking from the centre of the compass towards the point the ship is sailing upon.*

EXAMPLES.

Ex. 1. The course steered is N.W. by W. the wind N. by E., Leeway $1\frac{1}{4}$ points.

The ship has the starboard tacks on board; therefore, the Leeway ($1\frac{1}{4}$ points) allowed to the left of N.W. by W., gives corrected *Course* W. by N. $\frac{3}{4}$ N.

Ex. 2. Course by Compass S. by E., wind E. by S., Leeway $2\frac{3}{4}$ points.

The ship is on the port tack, then $2\frac{3}{4}$ points allowed to the right of S. by E., is S. by W. $\frac{3}{4}$ W., the Course corrected for Leeway.

Ex. 3. Course N.E. by N., the wind N.W. by N., the leeway 1 point.

The ship being on the *port* tack, 1 point to the *right* of N.E. by N. is N.E., the corrected *Course*.

Ex. 4. Course steered W. by S., the wind N.W. by N., leeway $3\frac{1}{2}$ points.

The ship is on the *starboard* tack, $3\frac{1}{2}$ points to the *left* of W. by S. is S.W. $\frac{1}{2}$ S., the Compass Course made good.

Correct the following Courses for Leeway:—

	COURSE STEERED.	WIND.	LEEWAY.
1.	S.S.W.	S.E.	$1\frac{1}{2}$
2.	S.W. $\frac{1}{2}$ W.	W.N.W.	$2\frac{1}{4}$
3.	N. by E.	E. by N.	$\frac{3}{4}$
4.	N.N.E. $\frac{1}{2}$ E.	N.W. $\frac{1}{2}$ N.	2
5.	N.W.	N.N.E.	2
6.	E.	N.N.E.	$3\frac{3}{4}$
7.	E.S.E.	S.	$2\frac{1}{2}$
8.	W.	S.S.W.	$1\frac{1}{2}$
9.	N.	E.N.E.	$1\frac{1}{4}$
10.	S.S.E.	E.	$2\frac{3}{4}$

	COURSE STEERED.	WIND.	LEEWAY.
11.	E. $\frac{3}{4}$ N.	N. by E.	$1\frac{3}{4}$
12.	W.S.W.	S.	$1\frac{1}{4}$
13.	N.W. $\frac{3}{4}$ N.	N.E. by E.	$1\frac{3}{4}$
14.	S.W. by W.	S. by E.	$2\frac{3}{4}$
15.	S. by E. $\frac{3}{4}$ E.	E. $\frac{1}{2}$ S.	$1\frac{1}{4}$
16.	N.W. by N.	W. by S.	$1\frac{1}{4}$
17.	N.E. $\frac{1}{4}$ E.	N. by W.	$1\frac{1}{2}$
18.	S.E. $\frac{1}{2}$ E.	S. by W.	$2\frac{1}{4}$
19.	W.N.W.	N.	$2\frac{3}{4}$
20.	N.N.W.	W.	$3\frac{1}{4}$

(a) *When the ship is* hove-to, *take the* middle point *between that to which she* comes up *and that to which she* falls off *for the* compass course, *and correct this for leeway.*

Examples.

Ex. 1. A ship lying-to under her mainsail, with her starboard tacks aboard, comes up E. by S., and falls off to N.E. by E., making 5 points leeway. What compass course does she make good?

The middle point between E. by S. and N.E. by E. is E. by N., then 5 points to the *left* hand gives N.N.E., the compass course made good.

Ex. 2. A ship lying-to under a close-reefed main-topsail, with her port (larboard) tacks on board, comes up S.S.W. and falls off to S.W. by W., making $2\frac{1}{2}$ points leeway. What compass course does she make good?

The middle point between S.S.W. and S.W. by W. is S.W. $\frac{1}{2}$ S., then $2\frac{1}{2}$ points to the *right* hand is W.S.W.

Ex. 3. A ship lying-to comes up S. by E. and falls off to S.E. by E., the wind being S.W., making 5 points leeway: required the compass course.

The middle point between S. by E. and S.E. by E. is S.E. by S., then 5 points to the *left* hand (the ship having starboard tacks on board) is East, the compass course made good.

Ex. 4. A ship lying-to with port tacks on board, comes up W. by S. and falls off N.W. by W., making 5 points leeway. What course does she make good?

The middle point between W. by S. and N.W. by W. is W. by N., then 5 points to the *right* hand is N.N.W., the course made good.

2. THE VARIATION OF THE COMPASS.

The needle points to the magnetic north, which in few parts of the world agrees with the true north, the difference between them is called the *Variation of the Compass*. It is said to be *easterly* when the north end of the needle is drawn to the eastward, and *westerly* when drawn to the westward of the true north: thus, when the north end of the needle points to that part of the horizon, which is true N.N.W. $\frac{1}{2}$ W., the *variation* is said to be $2\frac{1}{2}$ points west; but when it points to the N. by E. part of the horizon, the *variation* is said to be 1 point east. The variation is different in different places, and it is also subject to a slow change in the same place, and becomes alternately east and west. It also changes slightly at different times of the day.

Variation is one of the "corrections" in deducing the true course and bearing from the course and bearing observed with the compass. It is given on the charts used in navigation.

The method of correcting Courses for Variation will be readily understood by means of an example.

Suppose the variation of the compass is found to be two points east, that is, the needle is directed two points to the right of the north point of the heavens; then the N.N.W. point of the compass card will evidently point to the true north, and every other point on the card will be shifted round two points. If, therefore, a ship is sailing *by compass* N.N.W., or, as it is usually expressed, her compass course is N.N.W. her true course will be north; that is, *two points to the right of the compass course.* In a similar manner it may be shown that when the variation is two points westerly, the true course will be *two points to the left of the compass course.*

To find the true course, the compass course being given.

RULE XXVII.

Allow easterly *variation to the* right *of the* compass course.
,, westerly ,, left ,,
*looking from the centre of the card over the point to be corrected.**

Examples.

Taking the courses between North and South round by East.

Ex. 1. Course steered N.E. by E., variation $1\frac{3}{4}$ points *East*, then the *true course* (allowing the variation to the *right*) will be E. by N. $\frac{1}{4}$ N., or N. $6\frac{3}{4}$ points E.

Ex. 2. Course steered the same, viz., N.E. by E., variation $2\frac{3}{4}$ points *West*, then the *true course* (allowing the variation to the *left*) would be N.N.E. $\frac{1}{4}$ E., or N. $2\frac{1}{4}$ points E.

Ex. 3 Course by compass N.N.E., variation $2\frac{1}{4}$ points *West*, the *true course* $2\frac{1}{4}$ points to the left hand of N.N.E., or N. $\frac{1}{4}$ W.

Ex. 4. Compass course S. by E., variation $2\frac{1}{4}$ *East*, $2\frac{1}{4}$ points allowed to right of S. by E. is S. by W. $\frac{1}{4}$ W., or S. $1\frac{1}{4}$ W.

Ex. 5. Compass course S.E., variation $1\frac{1}{4}$ points *East*, then the *true course* (allowing the variation to the *right*) will be S.S.E. $\frac{3}{4}$ E., or S. $2\frac{3}{4}$ points E.

Ex. 6. But compass course S.E., variation $2\frac{1}{2}$ points *West*, then the *true course* (allowing the variation to the *left*) will be E. by S. $\frac{1}{2}$ S., or S. $6\frac{1}{2}$ points E.

Ex. 7. Compass course (as above) E. variation 2 points *West*, then allowing 2 points to the left gives *true course* E.N.E.

Ex. 8. Compass course E., variation $2\frac{3}{4}$ points *East*, then the *true course* (allowing the variation to the right hand) is S.E. by E. $\frac{1}{4}$ E.

Now proceeding to the courses between North and South round by West.

Ex. 9. Course by compass N.W. $\frac{1}{2}$ W. variation 2 points *West*, then the *true course* (allowing the variation to the *left*) will be W. by N. $\frac{1}{2}$ N., or N. $6\frac{1}{2}$ points W.

Ex. 10. Taking the same compass course, viz., N.W. $\frac{1}{2}$ W., when the variation is $1\frac{1}{2}$ points *East*, the *true course* (allowing the variation to the *right*) will be N.W. by N., or N. 3 points W.

Ex. 11. Again, compass course S.W. by S., variation $2\frac{3}{4}$ points *West*, the *true course* (allowing variation to the *left*) will be S. $\frac{1}{4}$ W.

Ex. 12. Compass course S.W. by S. (as before) variation $1\frac{3}{4}$ *East*, the *true course* (allowing the variation to the *right*) will be S.W. $\frac{3}{4}$ W., or S. $4\frac{3}{4}$ points W.

* The learner must be careful to remember when correcting his courses that he is to suppose himself *looking from the centre of the card over the point to be corrected.* When the learner places the compass card before him, mistakes very frequently occur in the application of the variation between the *east* and *west* points round by *south;* thus, —taking the compass with the north point placed before or from the observer—while an error could scarcely arise when correcting courses in the N.E. and N.W. quadrants, it would be different with the S.E. and S.W. quadrants, unless he bore in mind, that in the latter instances the compass card should be placed before him, as if he were facing the south. From what has been said it will be seen that in correcting courses, the significance of Right, on the face of the compass card, is *as the hands of a watch move over the dial,* and Left *the contrary direction.*

Ex. 13. Compass course S.S.W., variation $3\frac{1}{4}$ *West*, then allowing $3\frac{1}{4}$ W. to the left of S.S.W. gives S. by E. $\frac{1}{2}$ E., or $1\frac{1}{2}$ points E.

Ex. 14. Compass course W., variation $2\frac{1}{2}$ E., then the *true course*, (allowing $2\frac{1}{2}$ points to the *right*) is N.W. by W. $\frac{1}{2}$ W., or N. $5\frac{1}{2}$ points W.

Ex. 15. But with same compass course and variation $3\frac{1}{4}$ *West*, then allowing $3\frac{1}{4}$ points to the left of W., the *true course* is S.W. $\frac{3}{4}$ W., or S. $4\frac{3}{4}$ points W.

Ex. 16. Compass course N.N.W. $\frac{1}{2}$ W. variation $3\frac{1}{4}$ points *East*, then $3\frac{1}{4}$ points to the right of N.N.W. $\frac{1}{2}$ W., is N. $\frac{3}{4}$ E.

The learner should so familiarize himself with the compass card as to be able entirely to dispense with its use in correcting courses, and when he has acquired such knowledge, he will find the following rule serviceable, in which the points of the compass are treated numerically.

RULE XXVIII.

1°. *Put down the* points *and* quarter points *which the* compass course *is to the* right *or* left *of* North *or* South, *marking them* R. *or* L. *accordingly.*

2°. *Underneath put the* variation, *marking it also* R. *or* L., *according as it is* E. *or* W.

3°. *If the names are* alike, *take the* sum *with* that name *for the true course.*

(a) *When the* sum amounts *to* 8 points, *it is either* E. *or* W.

(b) *When the* sum exceeds 8 points, *take it from* 16 points, *the* remainder *is the true course to be reckoned from the* opposite point to that which the compass course is reckoned from.

That is, it is to be reckoned from the North if it had previously been reckoned from S., but marked S. if previously marked N.

4°. *If the names are* unlike, *take the* difference *and mark it the* same name *as the* greater.

(c) *If the variation being* subtractive, exceeds *the amount from which it has to be subtracted, take the points of the course* from *the* variation, *and name it the course towards* West *if it had previously been* Easterly, *but towards the* East *if it had been* Westerly.

(d) *Also bear in mind that* 0 points *is either* North *or* South *as the case may be.*

The following are examples of this method of applying the variation, and the numbers and letters in brackets refer to the rule as given above:—

1. Compass Courses:—S.S.W.; N. by E. ½ E.; W.S.W.; and E. by N. Variation 3½ points Easterly. Required the True Courses.

S.S.W.	N. by E. ½ E.	W.S.W.	E. by N.
2 R. of S.	1½ R. of N.	6 R. of S.	7 R. of N.
3½ R. [3°]	3½ R. [3°]	3½ R. [b]	3½ R. [b]
5½ R. of S.	5	— 9½ R. of S.	— 10½ R. of N.
S.W. by W. ½ W.	N.E. by E.	16	16
		6½ L. of N.	5½ L. of S.
		W. by N. ½ N.	S.E. by E. ½ E.

2. Compass Courses:—N.N.W.; S. by E.; W. ½ N.; and E. by S. Variation 2½ W.

N.N.W.	S. by E.	W. ½ N.	E. by S.
2 L. of N.	1 L. of S.	7½ L. of N.	7 L. of S.
2½ L. [3°]	2½ L. [3°]	2½ L. [b]	2½ L. [b]
4½ L. of N.	3½ L. of S.	— 10½ L. of N.	— 9½ L. of S.
N.E. ½ E.	S.E. ½ S.	16	16
		6 R. of S.	6½ R. of N.
		W.S.W.	E. by N. ½ N.

3. Compass Courses:—N.E. ½ E.; S.W. ¾ W.; N. by E.; and S. by W. Variation 2¼ points West.

N.E. ½ E.	S.W. ¾ W.	N. by E.	S. by W.
4½ R. of N.	4¾ R. of S.	1 R. of N.	1 R. of S.
2¼ L. [4°]	2¼ L. [4°]	2¼ L. [c]	2¼ L. [c]
2¼ R of N.	2½ R. of S.	1¼ L. of N.	1¼ L. of S.
N.N.E. ¼ E.	S.S.W. ½ W.	N. by W. ¼ W.	S. by E. ¼ E.

4. Compass Courses:—N.W. by W.; S.E. by E.; N. by W. ½ W.; and S. by E. Variation 3¼ points East.

N.W. by W.	S.E. by E.	N. by W. ½ W.	S. by E.
5 L. of N.	5 L. of S.	1½ L. of N.	1 L. of S.
3¼ R. [4°]	3¼ R. [4°]	3¼ R. [c]	3¼ R. [c]
1¾ L. of N.	1¾ L. of S.	1¾ R. of N.	2¼ R. of S.
N. by W. ¾ W.	S. by E. ¾ E.	N. by E. ¾ E.	S.S.W. ¼ W.

5. N.N.E., Variation 2 points W.; S. by E., Variation 1 point E.; W. by S., Variation 1 point E.; and E.S.E., Variation 2 points W.

N.N.E., Va. 2 W.	S. by E., Var. 1 E.	W. by S., Var. 1 E.	E.S.E., Var. 2 W.
2 R. of N.	1 L. of S.	7 R. of S.	6 L. of S.
2 L.	1 R.	1 R.	2 L.
0 [d]	0 [d]	8 R. of S. [a]	8 L. of S. [a]
N.	S.	W.	E.

6. N., Variation 2 pts. E.; S., Variation 2 pts. W.; and E., Variation 2 pts. E.

N., Var. 2 E.	S., Var. 2 W.	W., Var. 2 W.	E., Var. 2 E.
0 = N.	0 = S.	8 R. of S.	8 L. of S.
2 R. of N.	2 L. of S.	2 L.	2 R.
2 R. of N. [3°]	2 L. of S. [3°]	6 R. of S. [4°]	6 L. of S. [4°]
N.N.E.	S.S.E.	W.S.W.	E.S.E.

If the learner has carefully gone through the preceding examples, he will have noticed that *Easterly* variation in its application to Compass Courses *increases* them in the *N.E.* and *S.W.* quarters of the compass; and *decreases* them in the *N.W.* and *S.E.* quarters: it is therefore *additive* in the former, and *subtractive* in the latter cases. *Westerly* variation *decreases* the courses in the *N.E.* and *S.W.* quadrants, and *increases* it in the *N W.* and *S.E.*; and is therefore *subtractive* in the former cases, and *additive* in the latter.

We shall now proceed to illustrate the foregoing rule, which is very generally used in the correcting of courses.

1. Compass Courses:—N.N.E.; S. by W. ½ W.; W.N.W.; S.E. ½ E. Var. 3¼ E.

N. 2 E.	S. 1½ W.	N. 6 W.	S. 4½ E.
+ 3¼ E.	+ 3¼ E.	— 3¼ E.	— 3¼ E.
N. 5¼ E.	S. 4¾ W.	N. 2¾ W.	S. 1¼ E.
N.E. by E. ¼ E.	S.W. ¾ W.	N.N.W. ¾ W.	S. by E. ¼ E.

2. Compass Courses:—E.N.E.; W. by S.; N.N.W.; S. by E. Var. 3¼ E.

N. 6 E.	S. 7 W.	N. 2 W.	S. 1 E.
+ 3¼ E.	+ 3¼ E.	— 3¼ E.	— 3¼ E.
N. 9¼ E.	S. 10¼ W.	N. 1¼ E.	S. 2¼ W.
16	16	N. by E. ¼ E.	S.S.W. ¼ W.
S. 6¾ E.	N. 5¾ W.		
E. by S. ¼ S.	N.W. by W. ¾ W.		

3. Compass Courses:—N.E.; S.W. ½ S.; N.W. ½ N.; S.E. ¼ S. Var. 2¼ W.

N. 4 E.	S. 3½ W.	N. 3½ W.	S. 3¾ E.
— 2¼ W.	— 2¼ W.	+ 2¼ W.	+ 2¼ W.
N. 1¾ E.	S. 1¼ W.	N. 5¾ W.	S. 6 E.
N. by E. ¾ E.	S. by W. ¼ W.		

4. Compass Courses :—N. by E. ; S. by W. ¼ W. ; W. ½ N. ; E. by S. Var. 2¼ W.

N. 1 E.	S. 1¼ W.	N. 7½ W.	S. 7 E.
— 2¼ W.	— 2¼ W.	+ 2¼ W.	+ 2¼ W.
N. 1¼ W.	N. 1 W.	N. 9¾ W.	S. 9¼ E.
		16	16
		S. 6¼ W.	N. 6¾ E.

5. Compass Courses :—N.N.W. ¾ W. ; S.S.E. ¾ E. ; N.E. by E. ¼ E. ; S.W. by W. ¼ W.

N. 2¾ W.	S. 2¾ E.	N. 5¼ W.	S. 5¼ W.
— 2¾ E.	— 2¾ E.	+ 2¾ E.	+ 2¾ E.
0	0	N. 8 E.	S. 8 W.
North.	South.	East.	West.

Examples for Practice.

Correct the following Compass Courses for Variation :—

COMPASS COURSE.	VAR.	COMPASS COURSE.	VAR.	COMPASS COURSE.	VAR.
1. N.N.E.	2 E.	13. N.N.E.	2¼ W.	25. N. by E.	2½ W.
2. S.E. ½ S.	1½ E.	14. S.	2 W.	26. N. by W.	2¾ E.
3. S.W. ¼ W.	1¾ E.	15. W.	2½ E.	27. S. by E. ½ E.	3¼ E.
4. N.W. by W. ¼ W.	1¼ E.	16. S.S.W. ¾ W.	1¾ E.	28. E. by S.	24° W.
5. N.E. ½ N.	1½ W.	17. S.S.E.	1½ E.	29. N.N.W.	24° W.
6. S.S.E.	2 W.	18. E.N.E.	3½ E.	30. N. ¼ E.	24° W.
7. S.W. ¼ S.	1¾ W.	19. E. ½ S.	2½ W.	31. W.	24° W.
8. N.N.W. ¾ W.	2¼ W.	20. S. by W.	2½ W.	32. E.	24° W.
9. E. ½ N.	3 E.	21. N. ½ E.	½ W.	33. N.	24° W.
10. N.W. by N.	3¾ E.	22. W.	4¼ W.	34. S.	24° W.
11. S.W. ½ S.	4 W.	23. W. by S.	3½ E.	35. S. 60° E.	18° W.
12. N.	5 E.	24. W. by N.	2½ W.	36. N. 24° W.	36° E.

The learner may now proceed to correct the course steered for the combined effect of leeway and variation, and in doing so, when they are both to be applied in the *same* direction, take their *sum* and apply it in the same way; but when these corrections are to be applied in *opposite* directions take their *difference*, and apply the remainder in the same direction as the greater correction is to be applied: the result in either case is the true course.

	COMPASS COURSE.	WINDS.	LEEWAY.	VARIATION.
1.	N.E. by E.	S.E. by E.	¾	1¼ W.
2.	S.E. by S.	S.W. by S.	½	1¼ W.
3.	W.S.W.	N.W.	1¾	1¼ W.
4.	N.N.W.	N.E.	2¼	1¼ W.
5.	N.E. by N.	N.W. by N.	1	2½ W.
6.	S.S.E. ½ E.	E. ½ N.	1¾	2½ W.

1. N.E. by E.
5 R. of N.
¾ L. / 1¼ L. } 2 L.
—
3 R. of N.
or N. E. by N.

2. S.E. by S.
3 L. of S.
½ L.
1¼ L.
—
4¾ L. of S.
or S.W. ¾ W.

3. W.S.W.
6 R. of S.
1¾ L. / 1¼ L. } 3 L.
—
3 R. of S.
or S.W. by S.

4. N.N.W.
2 L of N.
2¼ L.
1¼ L.
—
5½ L. of N.
or N.W. by W. ½ W.

5. N.E. by N.
3 R. of N.
1 R. / 2½ L. } 1½ L.
—
1½ R. of N.
or N. by E. ½ E.

6. S.S.E. ½ E.
2½ L. of S.
1¾ R. / 2½ L. } ¾ L.
—
3¼ L. of N.
or S.E. ¾ S.

	COMPASS COURSE.	WINDS.	LEEWAY.	VARIATION.
7.	N. ½ E.	N.W. ½ W.	½	2½ W.
8.	S. by W.	W. by S.	¼	2½ W.
9.	N.W. ¼ W.	N. ½ E.	1¼	2½ W.
10.	W. by N.	S.W. by S.	¾	3¼ W.
11.	E. ½ S.	S. by E. ¾ E.	2¼	3¾ W.
12.	E.N.E.	S.E.	1¼	3½ E.

7. N. ½ E.
½ R. of N.
½ R. / 2½ L. } 2 L.
—
1½ L. of N.
—
or N. by W. ½ W.

8. S. by W.
1 R. of S.
¼ L. / 2½ L. } 2¾ L.
—
1¾ L. of S.
—
or S. by E. ¾ E.

9. N.W. ¼ W.
4¼ L. of N.
1¼ L.
2½ L.
—
8 L. of N.
—
or West.

10. W. by N.
7 L. of N.
¾ R. / 3¼ L. } 2½ L.
—
9½ L. of N.
16
—
6½ R. of S.
—
or W. by S. ½ S.

11. E. ½ S.
7½ L. of S.
2¼ L.
3¾ L.
—
13½ L. of S.
16
—
2½ R. of N.
—
or N.N.E. ½ E.

12. E.N.E.
6 R. of N.
1¼ L. / 3½ R. } 2¼ R.
—
8¼ R. of N.
16
—
7¾ L. of S.
—
or E. ¼ S.

	COMPASS COURSE.	WINDS.	LEEWAY.	VARIATION
13.	S.S.E. ½ E.	S.W. ½ S.	¾	3¼ E.
14.	W. by S.	N.W. by N.	2¼	3¼ E.
15.	S.E. ½ E.	E. by N. ½ N.	3¼	3¼ E.
16.	N.	W.N.W.	7½	3¼ E.
17.	{ up S.W. ½ W. / off S.W. by S. }	N.W.	6½	2½ W.
18.	{ up N. ½ E. / off N.W. by W. }	E.N.E.	7	2½ W.

13. S.S.E. $\frac{1}{2}$ E.
$2\frac{1}{2}$ L. of S.
$\left.\begin{array}{l}\frac{3}{4}\text{ L.}\\ 3\frac{1}{4}\text{ R.}\end{array}\right\}$ $2\frac{1}{2}$ R.
—
0
—
South.

14. W. by S.
7 R. of S.
$\left.\begin{array}{l}2\frac{1}{4}\text{ L.}\\ 3\frac{1}{4}\text{ R.}\end{array}\right\}$ 1 R.
—
8 R. of S.
—
West.

15. S.E. $\frac{1}{2}$ E.
$4\frac{1}{2}$ L. of S.
$\left.\begin{array}{l}3\frac{1}{4}\text{ R.}\\ 3\frac{1}{4}\text{ R.}\end{array}\right\}$ $6\frac{1}{2}$ R.
—
2 R. of S.
—
S.S.W.

16. N.

0
$7\frac{1}{2}$ R.
$3\frac{1}{4}$ R.
——
$10\frac{3}{4}$ R. of N.
16
——
$5\frac{1}{4}$
—

17. $\left\{\begin{array}{l}\text{up S.W. } \frac{1}{2}\text{ W.}\\ \text{off S.W. by W.}\end{array}\right.$

$4\frac{1}{2}$ R. of S.*
3 R. of S.
—
2)$7\frac{1}{2}$
—
Mid. pnt. $3\frac{3}{4}$ R. of S.
$\left.\begin{array}{l}6\frac{1}{2}\text{ L.}\\ 2\frac{1}{2}\text{ L.}\end{array}\right\}$ 9 L.
—
$5\frac{1}{4}$ L. of S.
—
S.E. by E. $\frac{1}{4}$ E.

18. $\left\{\begin{array}{l}\text{up N. } \frac{1}{2}\text{ E.}\\ \text{off N.W. by W.}\end{array}\right.$

$\frac{1}{2}$ R. of N.
5 L. of N.
—
2)$4\frac{1}{2}$
—
$2\frac{1}{4}$ L. of N.
7 L.
$2\frac{1}{2}$ L.
——
$11\frac{3}{4}$ L. of N.
16
——
$4\frac{1}{4}$ R. of S.
—
S.W. $\frac{1}{4}$ W.

Sometimes it may be desirable to express the Variation in degrees, in which case we proceed as follows:

RULE XXIX.

1°. *Correct the compass course for leeway as before directed, and convert the number of points thus found into degrees, marking them* R. *or* L., *according as they are* right *or* left *of* N. *or* S.

2°. *Underneath write the variation, marking it* R. *or* L., *according as it is* E. *or* W. *Take the* sum *with the name of* either, *if the names are* alike, *and the* difference, *with the name of the* greater, *if the names are* unlike. The result will be the number of degrees the *true course* is from N. or S., *according as the course as corrected for leeway, is reckoned from the* N. *or* S.

(a) *If in taking the sum the number of degrees* exceed 90°, *take the* supplement to 180°, *and reckon the* true course *from the* opposite *point to that* from *which the* course *corrected for* leeway *is reckoned; also change the letter* R. *or* L.

Examples.

COMPASS COURSE.	WINDS.	LEEWAY.	VARIATION.	TRUE COURSE.
S.W. $\frac{1}{2}$ S.	W. by N. $\frac{1}{2}$ N.	$\frac{3}{4}$	23° W.	S. 8° W.
N. by E.	E. by N.	$3\frac{1}{4}$	20° E.	N. 5° W.
W. $\frac{3}{4}$ N.	S.W. by S.	1	25° W.	S. 85° W.

* When hove-to, half the sum, when both on the same side of N. or S., is the middle point, but when on different sides of N. or S., half the difference.

3½ R. of S.	1 R. of N.	7¼ L. of N.
¾ L.	3¼ L.	1 R.
2¾ R.	2¼ L.	6¼ L. of N.
or 31° R. of S.	or 25° L. of N.	or 70° L.
23 L.	20 R.	25 L.
8 R. of S.	5 L. of N.	95 L. of N.
S. 8° W.	N. 5° W.	180
		85 R. of S.
		S. 85° W.

The following examples are intended as an exercise in the correcting of compass courses for leeway and variation :—

	COMPASS COURSE.	WINDS.	LEEWAY.	VARIATION.
1.	N.E. by E. ½ E.	N ½ W.	1¼	2¾ W.
2.	W. by S. ½ S.	N.W. by N.	2¼	1½ W.
3.	N.N.W. ½ W.	N.E.	2½	2¼ W.
4.	E. by S. ½ S.	S. by E.	1¼	2½ W.
5.	N.N.E.	E.	¾	3½ E.
6.	N. by E. ½ E.	N.W. ½ W.	2¾	2¼ E.
7.	S. by E. ½ E.	E. ½ S.	2¼	3 E.
8.	S.S.W. ¾ W.	W. ½ N.	1½	1¾ E.
9.	S. ¼ E.	S.W. by W. ¾ W.	3¼	3¾ W.
10.	W. by S.	N.W. by N.	2½	3¾ W.
11.	W.N.W.	N ½ E.	1¾	3¼ W.
12.	W.	N.N.W.	¾	¾ W.
13.	S.W.	W.N.W.	1½	3¾ W.
14.	S.	W.S.W.	1	¾ E.
15.	S.E. by S.	E. by N.	1½	2 W.
16.	E.	S.S.E.	3	2½ E.
17.	W.N.W.	N.	2½	4 W.
18.	S.S.W. ½ W.	S.E. ½ S.	5	3 E.
19.	N.	W.N.W.	7½	3¼ E.
20.	N. by E. ½ E.	N.W. ½ W.	2¼	2¼ W.
21.	N.W. ½ W.	N.N.E.	1¾	2½ E.
22.	E. by S. ¾ S.	N.N.E.	2¼	2½ E.
23.	E.S.E.	S.	2½	2½ E.
24.	S.S.W. ½ W.	W.	2¾	1¾ E.
25.	N. ¾ E.	E. by N. ½ N.	3	3 W.
26.	W. by S.	N.W. by N.	1¾	2¼ E.
27.	S.W. ½ S.	W. by N. ½ N.	5¼	4½ E.
28.	N.W. by N.	W. by S.	1¼	1 E.
29.	up N.E. by N. off N. by E.	E. by S.	6	3 W.
30.	up S. by E. off S. by W.	E. by S.	6	3 W.
31.	W. by N.	S.W. by S.	1	23½° W.
32.	S. by W. ½ W.	S.E. ½ E.	½	23½° W.
33.	S.S.E.	E.	1¼	23½° W.
34.	S.S.E.	S.W.	2½	23° W.
35.	S.W.	S.S.E.	3¼	23° W.
36.	N. by E.	E. by N.	1¼	18° E.

When it is required to deduce a compass course from a true course the converse process to Rule XXVII is pursued.

RULE XXX.

To find the compass course, the true course and variation being given.

Easterly variation allowed to the left.
Westerly „ „ right.

EXAMPLES.

Taking the courses between North and South round by East.

Ex. 1. Let the *true* course be N.E. by E., where the variation is 1¼ point *west*, the *compass* course (allowing westerly variation to the *right*) will be E.N.E. ¼ E.

Ex. 2. Taking the same course, viz., N.E. by E., where the variation is 1¼ point *east*, then the *compass* course (allowing easterly variation to the *left*) will be N.E. ¼ N.

Ex. 3. Suppose the *true* course to be S.E. by E., where the variation is 2¼ points *west*, the *compass* course (allowing westerly variation to the *right*) will be S.S.E. ¾ E.

4. But the same course, viz., S.E. by S., where the variation is 2¾ points *easterly*, will give the *compass* course (allowing easterly variation to the *left*) S.E. by E. ¾ E

Taking the courses between North and South, round by West.

5. Let the *true* course be N.W. by W., where the variation is 2½ points *west*, then the *compass* course (allowing westerly variation to the *right*) will be N.N.W. ½ W.

6. Suppose the course to be the same, viz., N.W. by W., where the variation is 2½ points *easterly*, the *compass* course (allowing easterly variation to the *left*) will be W. by N.

7. With the *true* course West, and the variation 2 points *west*, then the *compass* course (allowing 2 points to the *right*) will be W.N.W.

8. Taking the same course West, suppose the variation to be 2 points *east*, then the *compass* course (allowing 2 points to the *left*) is W.S.W.

9. With the *true* course S.W. ½ S., where the variation is 2¼ points *west*, then the *compass* course (allowing westerly variation to the *right*) will be S.W. by W. ¾ W.

10. But with the same course, viz., S.W. ½ S., where the variation is 1½ point *east*, the *compass* course (allowing easterly variation to the *left*) will be S.S.W.

Or, treating the points of the compass *numerically*, we may proceed according to Rule XXVIII, page 61, in every particular *except that the variation is to be allowed the* opposite way to that of correcting compass courses, viz., westerly variation is to be allowed to the *right* and marked R., and easterly variation is to be allowed to the *left* and marked L.

1. True Courses:—N.N.E.; S. by W. ½ W.; E. by N. ½ N.; W. by S. Var. 2½ W.

N.N.E.	S. by W. ½ W.	E. by N. ½ N.	W. by S.
2 R. of N.	1½ R. of S.	6½ R. of N.	7 R. of S.
2½ R.	2½ R.	2½ R.	2½ R.
4½ R. of N.	4 R. of S.	9 R. of N.	9½ R. of S.
		16	16
N.E. ½ N.	S.W.	7 L. of S.	6½ L. of N.
		E. by S.	W. by N. ½ N.

2. True Courses:—N.E. by E. ½ E.; S.W. by W.; E. by S. ¾ S.; N.W. by W. Variation 3¼ E.

N.E. by E. ½ E.	S.W. by W.	E. by S. ¾ S.	N.W. by W.
5½ R. of N.	5 R. of S.	6¾ L. of S.	5 L. of N.
3¼ L.	3¼ L.	3¼ L.	3¼ L.
2 R. of N.	1¾ R. of S.	10 L. of S.	8¼ L. of N.
		16	16
N.N.E.	S. by W. ¾ W.		
		6 R. of N.	7¾ R. of S.
		E.N.E.	W. by S. ¾ S.

3. True Courses:—N. by W. ½ W. and S. by E.; Variation 3¼ W. S. by W. and N. by E.; Variation 3¾ E.

N. by W. ½ W.	S. by E.	S. by W.	N. by E.
1½ L. of N.	1 L. of S.	1 R. of S.	1 R. of N.
3¼ R.	3¼ R.	3¾ L.	3¾ L.
1¾ R. of N.	2¼ R. of S.	2¾	2¾ L. of N.
N. by E. ¾ E	S.S.W. ¼ W.	S.S.E. ¾ E.	N.N.W. ¾ W.

3. LOCAL DEVIATION.

The deviation of the needle from the magnetic meridian is called *local deviation.** This correction of the compass is due to the influence of the iron on board ship on the magnetic needle, in deflecting it to the right or left of the magnetic meridian. The large quantity of iron now used in the construction and equipment of steamers, iron sailing vessels, and sometimes of wooden sailing vessels, produces a deviation from the magnetic north, which interferes seriously with the navigation of such vessels; and it is highly important that the officers of the Mercantile Marine should have a thorough acquaintance with the subject of *local attraction*, and with the correct method of applying to the different points of the compass, the "deviation," which is the effect of that attraction. The amount of the deviation arising from this local cause varies as the mass of iron changes its position with respect to the compass. If the iron were uniformly distributed in the ship, its effect in deflecting the needle would be inappreciable when the course is on the magnetic meridian, and greatest when the compass course is *east* or *west;* and in practice the deviation might be taken as equal to the greatest deviation multiplied by the sine of the compass course. But in general

* Deviation bears the same relation to *variation* that the latter does to the true place of the North point.

there is nothing like a uniform distribution of the masses of iron on board ship, and the deviation produced by local attraction is generally found experimentally, thus:—Place a compass (agreeing accurately with the binnacle compass when neither is acted on by local attraction) on the shore where it may be beyond the influence of the iron of the ship or any other local disturbing force, and take, simultaneously (known by signal), the bearing from each other of the compass on shore and the compass in the binnacle, as the ship's head is warped round to each point in succession of the compass on board, and the difference between the bearing of the compass on shore from the ship, and the opposite bearing to that observed on shore towards the ship's compass is the local deviation.

The deviation thus found is *easterly* when the reading by the shore compass is to the *right* of the compass on board; *westerly* when the reading by the shore compass is to the *left* of the reading by the compass on board.*

The directions of the ship's head having been taken by the compass in the ship, are therefore affected by the local attraction, and the apparent *compass bearing* of the ship's head differs from the true magnetic bearing by the amount of the local deviation due to the position of the ship. For instance, when the ship is apparently lying with her head east, it is not the true magnetic east, but supposing the local deviation to be one point easterly, the east point of the compass card will be drawn to E. by S., and the true magnetic direction of the ship's head will be E. by S.

The observations and tabulated results are incomplete until the *true magnetic* bearing of the ship's head at each observation is found.

The deviations may also be obtained from observations of a distant terrestrial object. The object selected for this purpose should be at such

* There is no error more frequently made than that of naming easterly deviation westerly, or westerly easterly. This arises chiefly from the explanation of E. and W. deviation given in books on navigation. Being informed that the deviation is westerly, if the north end of the needle is drawn to the west, and if drawn to the east, easterly; if the bearing by compass on board is too much easterly, the seaman frequently imagines that the north end of the needle is drawn to the east, whereas the contrary is the fact. The needle is drawn to the west, and by that means the east point on the compass card is drawn towards the direction of the body whose bearing is observed, which makes it appear by compass eastward. If the *correct* magnetic bearing be to the right of the bearing, by the compass on board, the deviation is easterly, if to the left, westerly.

a distance that the space through which the ship revolves shall make no sensible difference in its bearing. The ship is gradually swung round with her head successively upon each of the 32 points of the compass and the bearing of the object taken. The *true* magnetic bearing of the object taken from the ship is next determined, which is effected by taking the compass to some place on shore from whence the part of the ship where the compass stood and the object of which the bearings had been observed shall be in one with the observer's eye, or else in the exactly opposite direction. The bearing of the object from that spot will evidently be the *true* magnetic bearing from the ship by the compass. The difference between the *true* magnetic bearing of the object, and the successive bearings which were observed with the compass on board, when the ship's head was on the several points, will show the error at each of those points which was caused by the ship's iron.

Example.

When the ship's head lies N.N.E., let the binnacle compass bearing of the shore object or compass be N. 19° 30′ E., and the bearing of the binnacle compass from the shore compass be S. 27° 0′ W.: required the *deviation.*

The opposite point to S. 27° 0′ W. is N. 27° 0′ E., which is 7° 30′ to the right of N. 19° 30′ E. Hence the *deviation* is 7° 30′ E.

If during the operation of swinging, a haze obscures the shore compass, while the sun at the time is shining brightly, a number of points may be secured by time-azimuths, which otherwise might be lost. Time-azimuths are also advantageous where the second of the above methods cannot be used for want of an assistant observer for the shore compass; and when the first of the above methods are not available owing to the length of the ship (*e.g.* the Great Eastern) and the scope of the moorings, combined with the most distant objects in sight, not being sufficiently far off to render the difference of their bearings insensible as the ship swings round to the tide. In such cases *Godfray's Azimuth Diagram* will be found useful.

The following are the leading principles which have been developed in the course of repeated investigations of the magnetism of iron with reference to the compass-action and its changes in iron ships, viz.:—

1. That the magnetism of iron ships, in its action on the compass, may be represented by a vertical and horizontal iron or magnetic bar swinging round the compass. 2. That changes take place in the magnetic distribution and compass-action in iron ships. 3. That the changes take place in a ship's magnetism by changes of magnetic latitude. 4. That there are influences in a ship derived from the varieties of form and position (relatively to the compass) of particular masses of iron, which may act

as natural correctives. 5. That the plan of correcting the deviation of iron ships, either by a plate of soft iron, as proposed long ago by Mr. Barlow, or by a magnet or two magnets, as proposed by the present Astronomer-Royal (unless for limited voyages, as in the case of vessels plying between ports in the United Kingdom, or even in Europe, or plying between England and the United States), is unsafe, and in going to southern latitudes aggravates the error. 6. That the twisting and straining of the iron materials of a ship will tend, especially in ships recently launched, to alter the magnetic action on the compass. 7. That it requires time to effect the changes in a ships magnetic distribution, which ultimately may, in regions distant from the place of building, be effected.

Under the following circumstances great changes may be expected :—

1. In new ships first encountering heavy straining or rolling by sea. 2. In ships generally, if following a new voyage. 3. In ships running long on one course, and then changing the course. 4. Heavy weather first occurring.

No changes of importance may be expected under the following circumstances :—

1. In iron vessels long in use, and ordinarily pursuing the same voyage, because extreme deviation gets shaken down, as it were, in a medium or average state. 2. Great changes do not take place in the retentive magnetism, which is by far the greatest portion in latitudes not further south than the Mediterranean, because—3. In ships trading in the Channels (British, St. George's, &c.), or east and west to America, the liability to new and unexpected changes greatly diminishes.

Dr. Scoresby's suggestions for diminishing the dangers arising from the deviation of the compass are :—

1. A standard azimuth compass, to be placed on a high pedestal, where (on the Admiralty plan) a position of small deviation may be found. 2. A compass fixed at the mast-head (fitting the mast-head with brass work instead of iron work) for reference will, he believes, be best of all. This method, however, has not been sufficiently tried to be recommended for general adoption. 3. The wheel-compass required for ships engaged in the home trade, or traversing mainly parallels of latitude not southward of the Mediterranean, if adjusted with magnets and pieces of iron, may not then be unsafe, where reference may always be had to the standard for verification. 4. No standard compass in great distances. 5. Care to be taken, in the selection of compasses, that they have ample directive force. 6. Captains must, at every opportunity, take observations for the verification of their compass, by azimuths, stars, position of the land, &c. 7. Captains should have special knowledge for the charge of iron ships, because in this case, in addition to the ordinary dangers of navigation, there is a new source of error and misguidance, with respect to which it is most important they should never be thrown off their guard.

The plan adopted by the Royal Navy (which is preferable) of determining the amount of deviation, is by placing the ship's head on a number of compass points as nearly equidistant as possible, and the deviation on each point is observed, either by comparison with a compass, or by the bearing of a distant terrestrial object or of a heavenly body. The method of doing so by comparison with a compass is described above.

When the deviations have been observed on a few points only, it is requisite to compute the deviation on the intermediate points; and when from deviations on a large number of points, to compute the most probable value of the deviation on each point. The solution of these two problems may be effected mathematically by computing the co-efficients, A B C D E, from the observation by the method of least squares; and when the observatons are made on equidistant points the calculations are very simple. For the method of doing this see Supplement to the *Practical Rules for ascertaining or applying the Deviation of the Compass caused by the Iron in a Ship.*

For further information on this important subject the reader is referred to "The Practice of Navigation," by Lieut. Raper, R.N., pp. 69-80; "Practical Illustrations of the Necessity for Ascertaining the Deviation of the Compass," by the late Capt. E. Johnson, R.N., F.R.S.; "The Magnetism of Iron Ships and the Mariner's Compass," by Commander Walker; "Admiralty Manual for ascertaining and applying the Deviation of the Compass," by F. J. Evans, Master, R.N., F.R.S., and Archibald Smith, M.A., F.R.S.; also the "Practical Rules," by A. Smith, Esq., published by the Admiralty, containing a description of another method, called the Graphic Method, which is the most convenient one in ordinary cases, and proposed in different shapes by Mr. J. N. Napier, of Glasgow, and Capt. Ryder, R.N. The two methods are the same in principle. That of Mr. Napier will perhaps be found more convenient in construction by the expert; Capt. Ryder's simpler in use by the inexpert.

When the deviation is corrected, either by a table or by the Graphic Method, it must be remembered that the same table or the same curve can only be used in the same magnetic latitude, and as long as there is no material change in arrangement or condition of the iron of the ship. *Whenever any considerable change in the magnetic latitude of the ship takes place, a fresh table should be formed, and a fresh curve constructed, from fresh observations.*

The following is a Table of Deviations to which reference will be made hereafter. The Table is copied from the sheets issued by the Naval Department of the Board of Trade, for the use of candidates under examination :—

TABLE OF DEVIATIONS.

SHIP'S HEAD.	DEVIATION.	SHIP'S HEAD.	DEVIATION.
North	0° 22′ W.	South	0° 16′ E.
N. by E. . . .	1 46 E.	S. by W. . . .	1 50 W.
N.N.E.	3 20 E.	S.S.W.	3 16 W.
N.E. by N. . .	5 14 E.	S.W. by S. . .	4 48 W.
N.E.	7 14 E.	S.W.	6 16 W.
N.E. by E. . .	8 54 E.	S.W. by W. . .	7 40 W.
E.N.E	10 44 E.	W.S.W.. . . .	9 18 W.
E. by N. . . .	11 40 E.	W. by S. . . .	10 34 W.
East	10 44 E.	West	11 50 W.
E. by S. . . .	9 54 E.	W. by N. . . .	11 10 W.
E.S.E.	9 8 E.	W.N.W. . . .	10 16 W.
S.E. by E. . . .	7 20 E.	N.W. by W. . .	9 18 W.
S.E.	6 18 E.	N.W.	7 52 W.
S.E. by S. . . .	5 0 E.	N.W. by N. . .	6 18 W.
S.S.E.	3 24 E.	N.N.W. . . .	5 2 W.
S. by E. . . .	1 42 E.	N. by W. . . .	3 10 W.

RULE XXXI.

To find the correct magnetic course, having given the compass course and deviation.

Easterly deviation allow to the right.
Westerly ,, ,, left.

Correct the following compass courses for deviation:—

1. E.S.E. = 6 points L. of S.

6 points L. of S. = 67° 30′ L. of S.
Deviation (Table) 9 8 R.

Cor. *mag. course* 58 22 L. of S.

Or S. 58 22 E.

2. N.N.W. = 2 points L. of N.

2 points L. of N. = 22° 30′ L. of N.
Deviation (Table) 5 2 L.

Cor. *mag. course* 27 32 L. of N.

Or N. 27 32 W.

3. S.W. = 4 points R. of S.

4 points R. of S. = 45° 0′ R. of S.
Deviation (Table) 6 16 L.

Cor. *mag. course* 38 44 R. of S.

Or S. 38 44 W.

4. W. = 8 points R. of S.

8 points R. of S. = 90° 0′ R. of S.
Deviation (Table) 11 50 L.

Cor. *mag. course* 78 10 R. of S.

Or S. 78 10 W.

5. W. ¾ S. = 7¼ pts. R. of S. = 81° 34′ R. of S.
Deviation = 10 53 L.

S. 70 41 W.

W. by S. = 10° 34′ W.
West = 11 50 W.

4)1 16

Dev. for ¼ pt. = 0 19
Dev. W. by S. = 10 34 W.

Dev. for W. ¾ S. = 10 53 W.

6. N.W. by W. ¾ W. = 5¾ L. of N. = 61° 41′ L. of N.
Deviation = 10 1 L.

N. 71 42 W.

N.W. by W. = 9° 18′ W.
W.N.W. = 10 16 W.

Dev. for 1 pt. = 58
3

4)174

Changes of dev. for ¾ pt. = 0 43
Dev. for N.W. by W. = 9 18 W.

Dev. for N.W. by W. ¾ W. = 10 1 W.

7. N. ¼ E. = ¼ pt. R. of N. = 2° 49′ R. of N.
Deviation = 10 R.

Correct *magnetic course* N. 2 59 E.

Deviation at N. = 0° 22′ W.
N. by E. 1 46 E.

Change on 1 pt. 4)2 8

Change on ¼ pt. = 0 32 E.
Deviation at N. = 0 22 W.

Dev. on ¼ pt. = 0 10 E.

8. N. ½ W. = ½ pt. L. of N. = 5° 38′ L. of N.
Deviation = 1 46 L.

Correct *magnetic course* N. 7 24 W.

Deviation at N. = 0° 22′ W.
N. by W. 3 10 W.

Change on 1 pt. 2)2 48

Change on ½ pt. = 1 24 W.
Deviation at N. = 0 22 W.

Dev. on ½ pt. = 1 46 W.

Examples for Practice.

Correct the following courses steered as given in the Table, page 73.

1.	N.E. by N.	8.	S.E. by E.	15.	S.W. by S.	22.	West
2.	North	9.	N. by E. ½ E.	16.	S. ½ E.	23.	N.W ¼ W.
3.	N. by W. ½ W.	10.	South	17.	W. ½ S.	24.	S. ½ W.
4.	S.W. ½ W.	11.	W. ½ N.	18.	N.N.E. ½ E.	25.	W. by S. ½ S.
5.	W. ½ N.	12.	S.E. ¼ S.	19.	N. ¼ E.	26.	E. ½ S.
6.	S.S.W. ½ W.	13.	E. ¾ N.	20.	W. by N.	27.	East
7.	N.N.E. ½ E.	14.	N.W. ½ W.	21.	S. by E.	28.	W.N.W.

THE TRAVERSE TABLE.

In all collections of tables for the use of navigators there is inserted a table containing the *true difference of latitude* and *departure*, corresponding to certain *distances* (at intervals of one mile) up to 300 nautical miles, for every course, at intervals of a quarter point, and also of degrees, from 0 to a right angle (90°). Tables I and II (Raper or Norie).

In these Tables the *course* is found at the top of the table, when under four points or 45° ; but at the bottom of the table, when it exceeds four points or 45°. The first column contains the distance to 60 miles, the second column contains the difference of latitude, expressed in minutes and tenths, and the third column, similarly expressed, contains the departure; but if the course exceeds four points or 45°, the second column contains the departure, and the third column the difference of latitude. The other columns are a continuation of the former, exactly upon the same principle, and extending to 300 miles of distance.* (See Tables I and II, Norie and Raper.)

USE OF THE TABLE.

Given the course and distance, to find the difference of latitude and departure.

Examples.

Ex. 1. A ship sails N.W. ½ N. a distance of 78 miles: required the difference of latitude and departure by inspection.

The given course is 3½ points; and referring to Table I, we find the page devoted to this course to be page 14, Norie, or page 436, Raper's Navigation, in which against 78, in column headed *Dist.*, stands 60·3 under the head *Lat.*, and 49·5 under the head *Dep.* We conclude therefore that, for the given course and distance, the difference of latitude is 60·3 miles, and the departure 49·5 miles.

Ex. 2. Suppose the course to be 5½ points, and the distance 98 miles.

Then, since the course here exceeds four points, we look for it at the foot of the page, (page 10, Norie, or 432, Raper) and against 98 in the *distance* column we find 86·4 in the adjacent *departure* column, and 46·2 in the *difference of latitude* column, so that the difference of latitude made is 46·2, and the departure 86·4.

Ex. 3. Course N.E. by N., distance 129 miles: find diff. lat. and dep.

Enter Table I, and find 3½ points at the top, and in one of the columns marked *Dist.* find the distance 129, then in the columns opposite to this, marked *lat.* and *dep.*, stands the difference of latitude 107·3, and departure 71·7.

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* This table is constructed by solving a right-angled triangle, of which one angle represents the course, and the hypothenuse the distance; by giving these different and successive values, the corresponding values of the other two sides are found, which sides represent the true difference of latitude and departure. It is evident that the difference of latitude and departure for any course, are the departure and difference of latitude for the complement of that course, and hence the table is compactly arranged by interchanging the headings of the columns containing these elements at the top and at the bottom of the page, and using the top reading for courses from 0° to 45°, and the bottom reading for courses from 45° to 90°. This table may be used for a vast number of problems, depending for their solution on the relation of the several parts of a right-angled triangle, and, since all the relations between any two quantities may be expressed as functions of some angle, in terms of of the sine, cosine, or tangent, it may be used, in fact, as a general proportional table.

Ex. 4. Course E. by N. $\frac{1}{2}$ N., distance 264 miles: find diff. of lat. and dep.

Open Table I at $6\frac{1}{2}$ points, found at the bottom, and opposite the distance 264 stands departure 252·6, and difference of latitude 76·6.

Ex. 5. A ship sails N. 40° E., 50 miles: required the diff. of lat. and departure.

The course being less than 45°, is found at the top, and the distance being under 60 miles, is found in the left hand column; therefore on the page (56 Norie) is 40° at the top, and opposite to 50 in the distance column, marked Dist., is 38·3 *under* Lat., and 32·1 *under* Dep., the difference of latitude and departure required.

Ex. 6. A ship sails N. 64° W., 175 miles: required the diff. of lat. and departure. The course being more than 45°, is found at the bottom, in page 42, and opposite to the distance 175, is 76·7 *over* Lat., and 137·3 *over* Dep., which was required.

(*a.*) *When there are tenths in the distance*, in order to find diff. lat. and dep. in such case, take the distance as an entire number of miles, *i.e.*, as a whole number, and find the corresponding diff. lat. and dep., from each of which cut off the right hand figure, or tenths, and remove the decimal point one place to the left hand, which will give the required diff. lat. and dep. in miles, and tenths of a mile. The tenths, however, must be increased by 1, if the figure cut off is 5, or upwards.

Ex. 1. Course $3\frac{1}{2}$ points, distance 20·3; required the diff. lat. and dep. corresponding thereto.

With course $3\frac{1}{2}$ points, and distance 20·3, taken as 203, we get the diff. of lat. 156·9, dep. 128·8; now cut off the right hand figure of each (the 9 and 8), and shifting the decimal point one place to the left, we have diff. lat. 15·7, and dep. 12·9. It will be observed that the tenths are increased by 1, in each case, as the figures cut off in one case exceeds 5, and in the other amounts to 5.

Ex. 2. Required the diff. lat. and dep. corresponding to course $4\frac{1}{2}$ points, and dist. 24·3 miles.

With course $4\frac{1}{2}$ points, and dist. 24·3 (as 243 miles), we find diff. lat. 154·2, and dep. 187·8; hence we obtain, after dropping the tenths, and removing the decimal point in each one place to the left, 15·4, and 18·8, for the required quantities. The tenths in the dep., it will be observed, are increased by 1, since the figure dropped exceeds 5.

Ex. 3. N. 3 pts. W., and dist. 20·6 miles, give diff. lat. 17·1 N., and dep. 11·4 W.

Ex. 4. N. 65° E., and dist. 21·5 (as 215), give diff. lat. 90·9, and dep. 194·9, which is diff. lat. 9·1 N., and 19·5 E. It will be observed that the tenths are increased by 1, in each case, as the figure dropped exceeds 5.

(*b.*) If the distance exceeds the limits of the Traverse Table, take the half, the third, &c., so as to bring it within the limits, taking care to multiply the corresponding quantities by 2, 3, &c.

Ex. 5. Let the course be $3\frac{1}{4}$ points, and distance 435: required the corresponding diff. lat. and dep.

435 divided by 3 gives 145.

Course $3\frac{1}{4}$ points, and dist. 145 give diff. lat.	116·5 and dep.	86·4
	× 3	× 3
Diff. lat.	349·5 Dep.	259·2

If the distance had been 43·5, the diff. lat. would have been 35·0, and the dep. 25·9.

(*c*.) But when the distance is between 300 and 600, we may take out diff. of lat. and dep. for 300, and for the excess of 300, take the sum of the quantities thus found, cut off the last figure and remove the decimal point as before.

Ex. 6. Course $5\frac{3}{4}$ points, and distance 526: required the corresponding diff. of lat. and departure.

	Dist.	Diff. lat.	Dep.
Course $5\frac{3}{4}$ points, and dist.	300 give diff. lat.	128·3, and dep.	271·2
	226	96·6	204·3
	526	224·9	475·5

If the distance were 52·6, we should proceed as above, and then cutting off the last figure of each, and removing the decimal point one place to the left, the diff. of lat. is 22·5, and dep. 47·6. The tenths are increased by 1, in each case, as the figure cut off in one exceeds 5, and in the other amounts to 5.

Given the difference of latitude and departure, to find the course and distance.

If the difference of latitude be greater than the departure, the course will be found at the top; but if the departure be the greater, the course will be found at the bottom of the tables.*

Examples.

Ex. 1. A ship having sailed between the N. and E., until her difference of latitude is 199 miles, and her departure 144·6; required her course and distance.

In page 52 Norie, or page 474 Raper, these quantities will be found to correspond with 246 in the distance column, and with the angle 36° found at the top of the table; the course is, therefore, N. 36° E., and distance 246 miles.

Ex. 2. A ship having sailed between the S. and W., until her difference of latitude is 40 miles, and her departure 139·4 miles: required the course and distance.

In page 32 Norie, or page 454 Raper, the course answering to *latitude* 40 miles, and departure 139·4 miles, corresponds with the angle 74°, at the bottom of the table, and opposite the distance 145 miles, in the bottom of the table; the course is, therefore, S. 74° W., and distance 145 miles, which was required.

* Always seek for the larger of the two given numbers in the column next the distance, viz., the column marked "lat." at the top of the page, until the smaller quantity be found opposite in the column marked *dep.* at the top; being careful to remember that when the dep. is more than the diff. of lat., the course will be at the bottom of the page.

TRAVERSE SAILING.

Traverse Sailing is the case in plane sailing when the ship makes several courses in succession, the track being zigzag, and the direction of its several parts "traversing," or lying more or less athwart of each other. For all these actual courses and distances run on each, a single equivalent imaginary course and distance may be found, which the ship would have described had she sailed direct for the place of destination. Finding this course is called "Working a Traverse."

RULE XXXII.

1°. *Draw out a form similar to that given in the example following.*

2°. *In the column headed* Courses, *enter each course in succession; and in column* Dist., *enter the distance run on each course.*

3°. *Take out of the* Traverse Tables (Table I or II, Raper or Norie,) *the difference of latitude and departure to each course and distance, and enter the latitude in column* N. *or* S., *and the departure in column* E. *or* W., *according to the name of the course.*

Thus, if the course is S.E. by S. the difference of latitude must be entered in the column S., and the departure in the column E.; if the course is W. ¼ N. the difference of latitude must be entered in the column N., and the departure in the column W.; when the course is exactly North or South, there is no departure, and the whole distance is entered as difference of latitude in the corresponding column N. or S., as the case may be: so when the course is due East or West, there is no difference of latitude, and the whole distance run is entered as departure in the E. or W. column.

It may be advisable for a beginner, before he proceeds to take out the quantities from the Traverse Tables, to write a *dash* in all places *not* to be occupied by a difference of latitude or departure, in order to avoid writing a quantity in the wrong column. Such helps, however, are useless to an expert computer.

Ex. 1. A ship from the Dudgeon light, in lat. 53° 19′ N., sails S.S.E. ¼ E., 8 miles; E.N.E., 23 miles; N.W. by W. ½ W., 36 miles; E ¾ N., 48 miles; and N.W. ½ W., 46 miles: required the latitude arrived at, also the course and distance made good.

Courses.		Dist.	Diff. Lat.		Departure.	
			N.	S.	E.	W.
S.S.E. ¼ E.	= S. 2¼ E*	8	——	7·2	3·4	——
E.N.E.	= N. 6 E.	23	8·8	——	21·3	——
N.W. by W. ½ W.	= N. 5½ W.	36	17·0	——	——	31·8
E. ¾ N.	= N. 7¼ E.	48	7·0	——	47·5	——
N.W. ½ W.	= N. 4½ W.	46	29·2	——	——	35·6
* The courses are given in this double form merely as an illustration of the method of using them.			62·0	7·2	72·2	67·4
			7·2		67·4	
			54·8		4·8	

Table I, Raper, and Table I, Norie.
(See Explanation below.)

Explanation.—The courses and distances are entered in their proper columns, in the same order as they stand in the question: then in Traverse Table I, Norie or Raper, turn to the page with $2\frac{1}{4}$ points—which is found at the top, the course being less than 4 points—run the finger down the Dist. column till you come to 8, by the side of which stands 7·2 in Diff. lat. column, and 3·4 in Dep. column. Diff. lat. 7·2 is entered in the S. column, and Dep. 3·4 in the E. column, because the course is S. and E. (South and East). Next turn to the page of the Traverse Table with 6 points—found at the bottom, because more than 4 points—look for the distance 23, from the side of which take out Dep. 21·2, and Diff. lat. 8·8, which are entered under N. and E., because the course is N. and E. Proceed in a similar manner with the remaining courses.

The sum of the respective columns, N., S., E., and W., is next found, and the difference between the Northing, viz., 62·0, and the South, viz., 7·2, is taken, which leaves 54·8 N., which is the Diff. lat. made: the difference between the Easting 72·1, and West 67·3, leaves 4·8 E., departure.

We proceed in the next place to find the course and distance made good, thus:—

In Traverse Table II. $\left\{\begin{array}{l}\text{Diff. lat. } 54{\cdot}8 \text{ N.}\\ \text{and Dep. } 4{\cdot}8 \text{ E.}\end{array}\right\}$ give $\left\{\begin{array}{l}\text{Course N. } 5^\circ \text{ E.}\\ \text{Dist. } 55 \text{ miles.}\end{array}\right\}$ made good.

This is an illustration of the remark (see page 77) that when the diff. lat. is more than the dep., the course is less than 4 points, or 45°, and it is named from the N. towards the E., since the diff. lat. is N. and the dep. E.

Lat. left (or sailed from) Dudgeon light	53° 19′ N.	Lat. in is found according to Rule XXII, page 53.
Diff. lat. 54·8	= 55 N.	
Lat. in (or arrived at)	54 14 N.	

Ex. 2. A ship from Cape Espicheli, in lat. 38° 25′ N., sails as follows:—S.W. by W., 28 miles; W. by N., 55 miles: West, 47 miles; S.E. $\frac{3}{4}$ S., 25 miles; South, 101 miles; W. $\frac{3}{4}$ S., 72 miles: required the latitude in, also the course and distance made good.

Courses.	Dist.	Diff. Lat. N.	Diff. Lat. S.	Departure. E.	Departure. W.
S. 5 W.	28	—	15·6	—	23·3
N. 7 W.	55	10·7	—	—	53·9
W.*	47	—	—	—	47·0
S. $3\frac{1}{4}$ E.	25	—	20·1	14·9	—
S.*	101	—	101·0	—	—
S. $7\frac{1}{4}$ W. . . .	72	—	10·6	—	71·2
* See Rule Note, page 78.		10·7	147·3	14·9	195·4
			10·7		14·9
			136·6		180·5

We seek in the Traverse Table till the diff. of lat. 136·6, and dep. 180·5, are found opposite, each in their respective columns; the nearest to these are 180·5 and 136·0, which gives the course (at the bottom of page, dep. being the most) S. 53° W., and distance 22·6.

Lat. left	38° 25′ N.	The lat. in is found according to Rule XXII, page 53.
D. lat. 136·6	= 2 17 S.	
Lat. in (or arrived at)	36 8 N.	

Ex. 3. A ship from lat. 37° 24′ S., sails the following true courses:—S.W. by S., 20 miles; West, 16 miles; N.W. by W., 28 miles; S.S. E., 32 miles; E.N.E., 14 miles; S.W., 36 miles; required the lat. in, also the course and distance made good.

Courses.	Dist.	Diff. Lat.		Departure.	
		N.	S.	E.	W.
S. 3 W.	20	—	16·6	—	11·1
W.	16	—	—	—	16·0
N. 5 W.	28	15·6	—	—	23·3
S. 2 E.	32	—	29·6	12·3	—
N. 6 E.	14	5·4	—	12·9	—
S. 4 W.	36	—	25·5	—	25·5
		21·0	71·7	25·2	75·9
			21·0		25·2
			50·7		50·7

We seek in the several pages of the Traverse Table II, for the diff. lat. 50·7, and dep. 50·7; the nearest found to these are diff. lat. 50·9, dep. 50·9, give course S. 45° W., distance 72 miles.

The diff. lat. and dep. being of equal amount, the course is 45°, or 4 points, which illustrates the remark, page 49.

Lat. left	37° 24′ S.	The lat. sailed from being South, and the ship having sailed South, the ship has evidently increased her South lat., whence the sum of lat. from and d. lat. is taken to obtain lat. in.
Diff. lat. 50·7	= 51 S.	
Lat. arrived at	38 15 S.	

Ex. 4. A ship from lat. 20° 56′ N., sails (all true courses) N.W. by N., 20 miles; S.W., 40 miles; N.E. by E., 60 miles; S.E., 55 miles; W. by S., 41 miles; E.N.E., 66 miles: required the latitude in, also the course and distance made good.

Courses.	Dist.	Diff. Lat.		Departure.	
		N.	S.	E.	W.
N. 3 W.	20	16·6	—	—	11·1
S. 4 W.	40	—	28·3	—	28·3
N. 5 E.	60	33·3	—	49·9	—
S. 4 E.	55	—	38·9	38·9	—
S. 7 W.	41	—	8·0	—	40·2
N. 6 E.	66	25·3	—	61·0	—
		75·2	75·2	149·8	79·6
			75·2	79·6	
				70·2	

The Traverse Table being filled up, the sum of the Northings and Southings are both 75·2, and being of contrary directions, show that the ship has returned to the same parallel of latitude which she sailed from. The sum of the Eastings is 149·8, and that of the Westings 79·6; their difference 70·2 shows that the ship has gained so much to the Eastward, that being the greater. Consequently the *Course* is due *East*, and the *Distance* 70·2, the same as the departure,

Ex. 5. A ship sails from a place in lat. 1° 15′ N., the following true courses:—S.W. by W., 45 miles; E.S.E., 50 miles; S.W., 30 miles; S.E. by E., 60 miles; S.W. ¾ S., 63 miles: required the latitude in, also the course and distance made good.

Courses.	Dist.	Diff. Lat.		Departure.	
		N.	S.	E.	W.
S. 5 W.	45	——	25·0	——	37·4
S. 6 E.	50	——	19·1	46·2	——
S. 4 W.	30	——	21·2	——	21·2
S. 5 E.	60	——	33·3	49·9	——
S. 3¾ W.	63	——	50·6	——	37·5
			149·2	96·1 96·1	96·1

The Traverse Table being completed, the sum of the Southings is 149·2 miles, and to that amount the ship has altered her latitude. The miles of departure in the East column are 96·1, and those in the West column are also 96·1; but as the East and West departures destroy one another, and the ship has made no departure, she is under the same meridian as she sailed from: consequently the course is due S., and the distance sailed is equal to the diff. of lat., viz., 149·2. This is according to page 49.

Latitude left		1° 15′ N.	The ship being 1° 15′, or 75 miles, N. of the equator, must evidently be in S. lat. after making 149 miles of Southing. Thus, in subtracting one of the quantities from the other, the difference takes the *name* of the greater. Rule XXII, p. 53.
Diff. lat. 6,0)14,9·2			
	2 29·2	2 29 S.	
Latitude in		1 14 S.	

Ex. 6. A ship from latitude 46° 10′ N., sails as follows: S.E. ¼ E., 25 miles; S.E. ½ E., 18·9 miles; E. ¼ N., 12·4 miles; E.S.E. ¼ E., 14·5 miles; E.S.E., 21·6 miles; N.N.W. ¼ W., 16·4 miles; N. ¾ E., 7·8 miles; N. by E. ½ E. 13·7 miles; E. by N. ¼ N., 39·6 miles: required the lat. in, also the course and distance made good.

Courses.	Dist.	Diff. Lat.		Departure.	
		N.	S.	E.	W.
S. 4¼ E.	25	—	16·8	18·5	—
S. 4½ E.	18·9	—	12·0	14·6	—
N. 7¾ E.	12·4	0·6	—	12·4	—
S. 6¼ E.	14·5	—	4·9	13·7	—
S. 6 E.	21·6	—	8·3	20·0	—
N. 2¼ W.	16·4	14·9	—	—	7·1
N. ¾ E.	7·8	7·7	—	1·1	—
N. 1½ E.	13·7	13·1	—	4·0	—
N. 6¾ E.	39·6	9·7	—	38·4	—
		46·0	42·0	122·7	7·1
		42·0		7·1	
		4·0		115·6	

Explanation.—The course 4¼ points (found at the bottom of one of the pages in Table I), and dist. 25 (in Dist. column), opposite this last stands 16·8 diff. lat., and 18·5 dep., and as the ship is sailing on a S. and E. course, the diff. lat. is written in the Diff. lat. column, and the dep. in the East column.

To take out the next course and distance we proceed thus:—4½ points and dist. 18·9, taken as 189, give diff. lat. 119·9, and dep. 146·1; now removing the decimal point in each one place to the left we have diff. lat. 119·9 = 11·99, and dep. 146·1 = 14·61; we do not require to use both the decimal places, but if, as in the case with diff. lat., the second decimal figure amounts to 5, we add 1 to the first, and the diff. lat. thus becomes 12·0; if, as in the dep., the second figure is less than 5, we reject it, and thus the dep. is 14·6.

The third course is N. 7¾ E., and distance 12·4; then 7¾ points and dist. 124 (omitting the decimal point), give diff. lat. 06·1, and dep. 123·9; now dropping the tenths in each, namely, the 1 and the 9, and increasing the preceding figure by 1 in the last case, as the tenths exceed 5, we have, after removing the decimal point one place to the left, diff. lat. 0·6, and dep. 12·4.

Proceed in this way with the remaining courses, except the last, in which case the distance being more than 300, we proceed as follows:—

Course 6¾ points, and dist.	300	give diff. lat.	72·9,	and dep.	291·0
	96	”	23·3,	”	93·1
Therefore course 6¾ pts. and dist.	396	”	96·2,	”	384·1

Now cutting off the last figure of each, the 2 and the 1, and removing the decimal point one place to the left, we have diff. lat. 9·6, and dep. 38·4.

Lat. left	46° 10′ N.	Diff. of lat. 4·0, and dep. 115.6, give course N. 88° E., and dist. 116 miles.
Diff. lat.	4 N.	
Lat. in	46 14 N.	

EXAMPLES FOR PRACTICE.

1. A ship from the Texel, in lat. 52° 58′ N., sails W. by N., 44 miles; S. by E., 45 miles; W. by S., 35 miles; S.S.E., 44 miles; W.S.W. ½ W., 42 miles: find diff. lat. and dep., the course and dist. made good, also the lat. arrived at.

2. A ship from Heligoland, lat. 54° 12′ N., sails W.S.W., 12 miles; N.W., 24 miles; S. by W., 20 miles; N.W. by W., 32 miles; S. by E., 36 miles; W. by N. ½ N., 42 miles; S.S.E. ½ E., 16 miles; W. ¾ N., 45 miles: required diff. lat. and dep., course and dist. made good, also the lat. arrived at.

3. A ship sails from lat. 3° 50′ N., S.S.W., 112 miles; S. by E., 86 miles; S.S.E., 112 miles; S. by W., 86 miles: find diff. lat. and dep., the course and dist. made good, also the lat. arrived at.

4. Yesterday we were in lat. 19° S., and since then have sailed S.E. ½ S., 13 miles; S. by E., 19 miles; S.E. by E., 22 miles; E. by S. ¼ S., 32 miles; N.N.E., 20 miles; N. by W. ¼ W., 27 miles; N.E. by E. ½ E., 24 miles; S.W. ¼ S., 10 miles.

5. A ship from lat. 1° N., sails East, 8 miles; E. ¼ N., 20 miles; S.E. by E., 33 miles; S. ¾ W., 31 miles; N.E. ½ N., 43 miles; South, 28 miles; S. ¾ E., 21 miles; S. by W. ¼ W., 12 miles: required diff. lat. and dep., course and dist. made good, and also the lat. in.

6. A ship from lat. 1° 10′ S., sails E. by N. ½ N., 56 miles; N. ¼ E., 80 miles; S. by E. ½ E., 96 miles; N. ¼ E., 68 miles; E.S.E., 40 miles; N.N.W. ½ W., 86 miles; E. by S., 65 miles: find diff. lat. and dep., course and dist. made good, also the lat. in.

7. A ship from lat. 1° 2′ S., sails N.N.E., 22 miles; N. by W., 30 miles; N.E. by E., 40 miles; E.S.E., 25 miles; S.S.W., 18 miles; N.W. ½ N., 50 miles; N.E. ½ E., 42 miles; W. ½ S., 45 miles; S.W. by S., 20 miles; E. ¾ N., 62 miles: find diff. lat. and dep., the course and dist. made good, and the lat. arrived at.

8. A ship from the Lizard, in lat. 49° 58′ N., with the wind at N.E., steers W. ½ S. (true), 89 miles; the wind veering to the Westward, she is close-hauled, and sails as follows:—North, 22 miles; S.W., 50 miles; N.W. by W., 30 miles; S.S.E., 14 miles; and W.S.W. ½ W., 42 miles: find the diff. lat. and dep., the direct course and dist. made good, and the lat. of ship.

9. A ship from lat. 47° 12′ N., sails S.S.W., 17 miles; E.N.E. ¼ E., 14·3 miles; S.W. ½ W., 14·9 miles; S.E., 15·1 miles; N.W. ½ N., 15·1 miles; E. by N., 15·6 miles; S.W. ¼ W., 16·9 miles; and S. ¾ E., 8 miles.

10. A ship from lat. 55° 1′ N., sails S.E. by E. ¾ E., 18 miles; N. ½ E., 12·4 miles; N.N.W., 12·1 miles; S.S.W. ½ W., 10·5 miles; and S. by E., 95·5 miles: find diff. lat. and dep., course and dist. made good, also lat. in.

11. A ship from lat. 38° 40′ N., sails N. ¾ E., 9·6 miles; N. by E. ¼ E., 23 miles; S.E. by E., 11·5 miles; S.E. by E. ½ E., 10·3 miles; E.S.E., 12 miles; S.E. ¾ E., 11·6 miles; S.E. by E., 15·7 miles; E. ½ N., 14·1 miles; East, 7·3 miles; E. ½ S., 6·8 miles; and West, 24 miles.

12. A ship from lat. 56° 59′ N., sails S. 42° W., 19 miles; N. 10° W., 20·2 miles; S. 17° E., 11·1 miles; N. 46° E., 8·1 miles; S. 51° W., 10·8 miles; S. 67° E, 19·3 miles; S. 43° E., 8 miles; N. 84° W., 15 miles: find diff. lat. and dep., the course and dist. made good, also the lat. arrived at.

13. A ship from the Equator, sails by compass, S.W. ¾ W., 62 miles; S. by W., 16 miles; W. ¼ S., 40 miles; S.W. ¾ W., 29 miles; S. by E., 30 miles; and S. ¾ E., 14 miles. Variation 20° W. Required her lat. in and the course and dist. made good.

14. A ship from lat. 34° 18′ S., sails as follows:—E. by S., 20·1 miles; W.S.W., 15·1 miles; W by S. ¼ S., 15 miles; E. by N. ¾ N., 31·2 miles; N.W. ¾ W., 23 miles; S.E. ½ E., 11·6 miles; S.E. by E ½ E., 10·6 miles; and N.W. ¼ W., 16 miles: required the lat. in, also the course and distance made good.

15. A ship sails from lat. 0° 49′ S., the following (true) courses:—N.W. ¼ W., 7·6 miles; N.W. ¼ N., 5·8 miles; N.N.W. ¾ W., 4 miles; N. by W. ¾ W., 6 miles; N.N.W. ¼ W., 2·4 miles; and S.S.W. ¾ W., 65·2 miles.

16. A ship from lat. 1° 10′ N., sails as follows:—S.W. by W. ¼ W., 15 miles; S.S.E. ¾ E., 11·1 miles; S.S.E., 24·3 miles; N.N.W. ¾ W., 17·7 miles; N.E. by E. ¼ E., 12·1 miles; S.W. by W. ¼ W., 20·5 miles; S.S.E. ¾ E., 28·2 miles; E. ¼ N., 48 miles.

PARALLEL SAILING.

When a ship sails on a parallel of latitude—that is, when her course is due East or due West—the distance or departure so made good is converted into difference of longitude by

RULE XXXIII.

1°. *Take out of the Tables the log. secant of latitude (rejecting* 10 *from index), and the log. of departure made good.*

2°. *Add these logs. together, and find the nat. number corresponding thereto.* The result is the difference of longitude required.

In parallel sailing the latitude being constant, the difference of longitude bears a constant ratio to the distance, and all problems may be completely solved by the solution of a right angled plane triangle, and therefore by inspection of the Traverse Table by

RULE XXXIV.

With the latitude of the parallel as a course, *and the distance sailed on it as* difference of latitude, *the corresponding* distance, *in the Traverse Table, is the* difference of longitude.

Examples.

Ex. 1. In lat. 29° 51′ S., the dep. made good 161 miles; required the diff. of long.

Lat. 29° 51′	Secant	0·061815
Dep. 161	Log.	2·206826
	Log.	2·268641

Diff. of long. 185·6

In Traverse Table II, lat. 30° as course, dep. 161·1 in lat. column, give diff. long. 186 miles in dist. column.

Ex. 2. A ship sailed 94·6 miles on the parallel 64° 38′ N.; required diff. long.

Lat. 64° 38′	Secant	0·368141
Dep. 94·6	Log.	1·975891
	Log.	2·344032

Diff. of long. 220·8.

In Traverse Table II, lat. 64° as course and dep. 94·7 give diff. lat. in dist. column 216 miles; and course 65°, and dep. 94·7, give diff. long. in dist. column 224 miles; therefore the diff. long. for $64\frac{1}{2}°$ will $= 216 + 224 \div 2 = 220$ miles.

Ex. 3. From long. 0° 59′ W., the dep. made was 125 East on the parallel of 52°; required the long. in.

Lat. 52°	Secant	0·210658
Dep. 125	Log.	2·096910
	Log.	2·307568

Diff. of long. 203·0.

Diff. long. 6,0)20,3

3 23 = 3° 23′ E.
Long. left 0 59 W.

Long. in 2 24 E.

Ex. 4. A ship from long. 179° 20′ W. sails 109 miles West, on the parallel of 61° 25′. what is the long. in.

Lat. 61° 25′	Secant	0·320176
Dep. 109′	Log.	2·037426
	Log.	2·357602

Diff. of long. 228·8 W.

6,0)22,9

3 49

3° 49′ W.
179 20 W.

Long. in 183 9 W.
360 0

Or 176 51 E.

Ex. 5. In lat. 23° 39′ N., the dep. made good was 528 miles; required the diff. of long.

Lat. 23° 39′	Secant	0·038098
Dep. 528	Log.	2·722634
	Log.	2·760732

Diff. of long. 576·4.

Ex. 6. In lat. 47° 53′, the dep. made good was 765 miles, required the diff. of long.

Lat. 47° 53′	Secant	0·173509
Dep. 765	Log.	2·883661
	Log.	3·057170

Diff. of long. 1140·7.

Examples for Practice.

In each of the following examples the difference of longitude is required:—

	Lat. in.	Dep.		Lat. in.	Dep.
1.	6° 7′ N.	249′ W.	7.	64° 16′ N.	265′·7 W.
2.	19 48 S.	324 E.	8.	51 28 S.	70·9 E.
3.	39 57 N.	398 W.	9.	37 0 N.	94 W.
4.	51 17 N.	294·8 W.	10.	60 0 S.	204 E.
5.	60 0 N.	74·0 W.	11.	11 15 N.	365 W.
6.	46 37 S.	352 E.	12.	54 53 S.	342 E.

Remarks.—The method of parallel sailing will apply correctly enough for all practical purposes to cases where the course is nearly east and west (true). In latitudes higher than 5°, when the distance does not exceed 300 miles, the departure may be used at once for the difference of longitude, the resulting error scarcely exceeding one mile.

MIDDLE LATITUDE SAILING.

Middle Latitude Sailing relates to the conversion of the departure into difference of longitude, and the difference of longitude into departure, when the ship's course lies obliquely across the meridian, that is, when besides departure, she makes difference of latitude.

Suppose a ship, in going on the same course, from latitude 40° to latitude 44°, makes 100 miles departure: this departure, if made good altogether in latitude 40°, would give 130·5 difference of longitude by Rule XXXIII, page 84; and again, if made good in latitude 44°, it would give 139 difference of longitude. Now, since the ship has sailed between these two parallels, and not on either of them exclusively, her real difference of longitude must be between 130·5 and 139, and therefore we may conclude it to be not far from that which would result from a departure made good altogether in the *middle parallel;* hence the name *Middle Latitude Sailing.* Middle latitude sailing then, is founded on the consideration that the arc of the parallel of middle latitude of two places intercepted between their meridians, is nearly equal to the departure. If we conceive the ship to sail along this middle parallel, we may apply the principle of *parallel sailing* to the cases in point. In parallel sailing the departure (or distance) and difference of longitude are connected by the relation, dep. = diff. of long. × cos. lat. When the ship's course lies obliquely across the meridian, making good a difference of latitude, a modification of this formula gives the formula for middle latitude sailing, dep. (nearly) = diff. of long. × cos. mid. lat.; or, in logarithms, log. dep. = log. diff. of long. + log. cos. mid. lat. — 10. Middle latitude sailing has thus the same two cases as parallel sailing, and accordingly the rules for inspection, computation already given, Rule XXXIII, page 84, apply equally to this sailing, observing merely to read *middle latitude* for *latitude.*

To find the latitude and longitude in, the course and distance from a known place being given by Traverse Table and Middle Latitude.

RULE XXXV.

1°. *With the given* course *and* distance *enter the Traverse Table, and take out* true difference of latitude and departure (see page 75).

2°. *With* difference of latitude *and* latitude from, *find* latitude in (see Rule XXII, page 53).

3°. *Get the* middle latitude, *as directed,* Rule XXIII, page 54.

4°. *With the middle latitude as* course, *look in the* difference of latitude *column for the* departure, *the corresponding* distance *at the top is the* difference of longitude.

5°. *With* difference of longitude *and* longitude from *get* longitude in, *as in* Rule XXV, page 56.

NOTE.—When the *departure* to be looked for as *difference of latitude* at the middle latitude, is beyond the limits of the Table, one-half, one-third, &c., must be used, and the resulting *difference of longitude* multiplied by the divisor, in order to get the whole *difference of longitude.*

EXAMPLES.

Ex. 1. A ship from lat. 52° 6′ N., long. 35° 6′ W., sailed S.W. by W., 256 miles; required her latitude and longitude in.

Course S. 5 pts. W. } give diff. lat. 142·2, and dep. 212·9 (see page 75).
Distance 256 miles }

6,0)14,2	Diff. lat.	2° 22′ S.	2)212·9
2 22	Lat. from	52 6 N.	½ dep. 106·4
	Lat. in	49 44 N.	
		2)101 50	
	Mid. lat.	50 55	

Mid. lat. 51° as course (Table II), and half dep. 106·4, in diff. lat. column, give in dist. column 169 miles, the half the diff. of long. Then 169 × 2 = diff. long. 338.

6,0)33,8		5° 38′ W.
5 38	Long. from	35 6 W.
	Long. in	40 44 W.

Explanation.—The difference of latitude and departure are found as described in page 75. The latitude in is found by Rule XXII, page 53; and thence the middle latitude, by adding the latitude from and latitude in together, and dividing by 2 (see Rule XXIII, page 54). The departure exceeding the limits of the Tables, the half is taken. Then with *middle latitude* as a *course*, and *half the departure*, in *difference of latitude* column, half the difference of longitude is found in the *distance* column. This being doubled (as half the departure was taken) and divided by 60, gives the difference of longitude expressed in degrees and minutes. The ship is in *West* longitude, *sailing West*, add difference of longitude to longitude left to obtain longitude in (Rule XXV, page 56).

This is the usual case at sea of working the Day's Work.

Ex. 2. A ship from lat. 48° 27′·4 N., and long. 29° 12′ W., sails N.E. by N., 22·5 miles: required the latitude in, also the longitude in.

Course N.E. by N. = 3 pts.; then 3 pts. and dist. 22·5 give diff. lat. 18·7, and dep. 12·5 (see page 75).

Diff. lat.	0° 19′ N.
Lat. from	48 27 N.
Lat. in	48 46 N. (Rule XXII, page 53.)
	2)97 13
Mid. lat.	48 36

Mid. lat. 48½° as course, and dep. as diff. lat., give in dist. column 19 miles, which is the diff. of long.

Diff. long.	0° 19′ E.
Long. left	29 12 W.
Long. in	28 53 W.

(To find mid. lat., see Rule XXIII, p. 54.) (The long. in is found by Rule XXV, p. 56.)

Ex. 3. Lat. from 58° 13′ N., long. from 3° 33′ E., course S.S.E. ¼ E., distance 213 miles: required latitude and longitude in.

Course 2¼ points, and dist. 213 miles, give diff. lat. 192·6, and dep. 91·1.

6,0)19,2·6		
3 12·6	or	3° 13′ S.
	Lat. from	58 13 N.
	Lat. in	55 0 N.
		2)113 13
	Mid. lat.	56 36

The mid. lat. is here 56½°.

Mid. lat. 56° as course, and dep. 91·1 as diff. lat., give in *dist.* column 163; and mid. lat. 57° as course, and dep. 91·0, give in *dist.* column 167. Then 163 + 167 = 330, which divided by 2, gives diff. long. 165 miles.

6,0)16,5		
2 45	or	2° 45′ E.
	Long. from	3 33 E.
	Long. in	6 18 E.

Ex. 4. A ship from the Lizard, in lat. 49° 57′ N., sails W.S.W., 163 miles, variation 2½ points W.: required the latitude come to, and difference of longitude.

W.S.W. by compass is (allowing 2½ points westerly variation) S.W. ½ S. true, which in Table II, and dist. 163, gives diff. lat. 126, and dep. 103·4.

6,0)12,6		
2 6	or	2° 6′ S.
	Lat. left	49 57 N.
	Lat. in	47 51 N.
		2)97 48
	Mid. lat.	48 54

Then mid. lat. 48° 54′, say 49°, as a course, and dep. 103·4, found in the lat. column, opposite to which, in the dist. column, is 158 nearest, the difference of longitude.

Ex. 5. Sailed from A, in lat. 50° 48′ N., long. 1° 10′ W., S. 41° E., 275 miles.

Entering Traverse Table II with *dist.* 275 miles, and *course* 41°, the *true diff. lat.* is 207′·5, or 3° 27′·5 S.; applying this to *lat. from*, the *lat. in* is 47° 20′·5 N. The corresponding *dep.* is taken out at the same opening, which is 180′·4. The *mid. lat.*, or half sum of *lat. from* and *lat. in*, is 49° to the nearest degree. The *dist.* corresponding to 49° as a course, and 180′·4 in *diff. lat.* column, is found to be 275′, in degrees 4° 35′ E., which is the *diff. long.* Applying this to the *long. from* 1° 10′ W., we have the *long. in* 3° 25′ E.

Examples for Practice.

In each of the examples following, the latitude and longitude arrived at are required to be found, having given the latitude and longitude from, with the course and distance sailed.

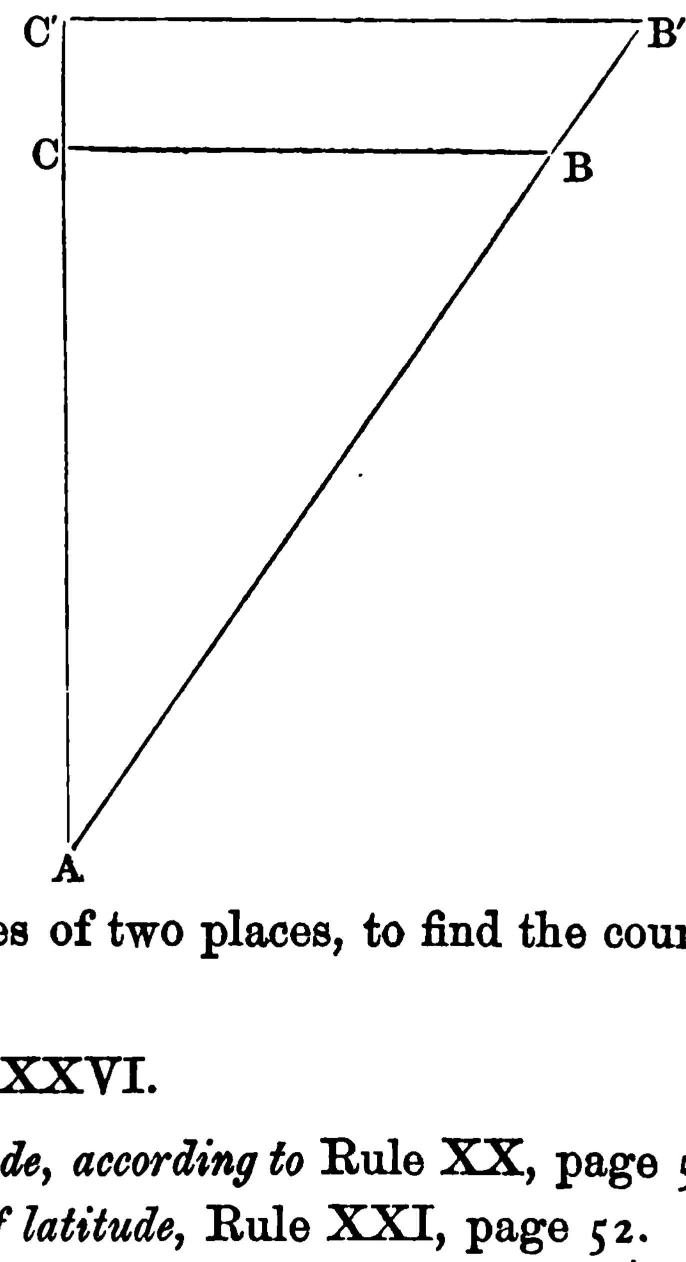
	LAT. FROM.	LONG. FROM.	COURSE.	DIST.
1.	25° 35′ N.	60° 0′ W.	E.N.E.	296
2.	32 30 N.	25 24 W.	N.W. by W. ½ W.	212
3.	39 30 S.	74 20 E.	S.W. by W. ¾ W.	210
4.	46 24 S.	178 28 E.	S.E. ¾ E.	278
5.	20 29 N.	179 10 W.	W. by S. ½ S.	333
6.	0 56 N.	29 50 W.	S. 47° E.	168

MERCATOR'S SAILING.

MERCATOR'S sailing, like middle latitude sailing, relates to finding the difference of longitude a ship makes when sailing on any oblique rhumb, and is a perfectly general and rigorously true method, which the other is not.

Mercator's sailing is characterised by the use of the *Table of meridional parts*, and the chart constructed by means of it called *Mercator's chart.* With the assistance of this Table, the rules of plane trigonometry suffice for the solution of all the problems.

In the triangle ACB let A be the course, AB the distance, AC the true difference of latitude, CB the departure; then corresponding to AC the table of meridional parts gives AC′, the meridional difference of latitude, and completing the right-angled triangle AC′B′, C′B′ will be the difference of longitude. In addition then to the three canons of *plane sailing* which can be deduced from the triangle ACB, the triangle AC′B′ gives the characteristic canon of *Mercator's sailing* (since C′B′ = AC′ tang. A) diff. long. = mer. diff. lat. + tang. course.



Given the latitudes and longitudes of two places, to find the course and distance between them.

RULE XXXVI.

1°. *Find the true difference of latitude, according to* Rule XX, page 50.

2°. *Find the meridional difference of latitude,* Rule XXI, page 52.

3°. *Next find the difference of longitude,* Rule XXIV, page 54.

4°.* To find the course.—*From the log. of diff. of longitude (increasing its index by* 10*), subtract the log. of meridional diff. of lat.: the remainder is*

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* From the formulæ:—

$$\text{Tang. Course} = \frac{\text{Diff. long.}}{\text{Mer. diff. lat.}} \qquad \therefore \text{log. tang. } \textit{course} - 10 = \text{log. diff. long.} - \text{log. mer. diff. lat.}$$

$$\text{Dist.} = \frac{\text{True diff. lat.}}{\text{Cos. course}} \qquad \therefore \text{log. } \textit{dist.} = \text{log. true diff. lat.} + \text{log. sec. course} - 10.$$

the tangent of course, which take out of the tables, and place before it the letter of diff. of lat., and after it the letter of diff. of long.

5°. To find the distance.—*To the secant of course (rejecting* 10 *from the index), add the log. of diff. of lat.: the sum is the log. of distance, the natural number corresponding to which find in the tables.*

EXAMPLES.

Ex. 1. Required the course and distance from Tynemouth light to the Naze of Norway.

Lat. Tynemouth	55° 1′ N.	Mer. parts	3970	Long. Tynemouth	1° 25′ W.
Lat. Naze	57 58 N.	Mer. parts	4291	Long. Naze	7 2 E.
	2 57	Mer. diff. lat.	321		8 27
	60				60
Diff. of lat.	177 N.			Diff. of Long.	507 E.

The lats. having *like* names their *difference* is taken and reduced to miles, and since the lat. *to* is to the *north* of lat. *from*, the ship must sail to the *northward*, whence the diff. lat. is marked N. The *difference* of the meridional parts is taken as the *lats.* are both of the *same* name. The longs. being of *different* names the *sum* is the diff. of long. which is reduced to miles, and since the ship has to pass from West long. to East long., she must steer Eastward to do so. The diff. of long. is therefore marked E.

To find the Course.			*To find the Distance.*		
Diff. long. 507	Log. (+ 10)	12·705008	Course 57° 39′ 38″	Secant	0·271700
Mer. diff. lat. 321	Log.	2·506505	Diff. of lat. 177	Log.	2·247973
	Tang.	10·198503		Log.	2·519673
Course N. 57° 39′ 38″ E.			Distance 330·9.		

To find the course we look for the tabulated logarithmic tangent nearest, and not exceeding, the given tangent, which we find to be 10·198325, the corresponding angle to which is 57° 39′; we next take the difference of the tabulated tangent thus found and the given tangent, annex two cyphers, and divide by the difference (466) found in corresponding column of difference, the quotient (38) is the additional seconds for the tangent, whence the course is N. 57° 39′ 38″ E. *(see Rule, pages* 40 *and* 41*)*. The secant of course is next taken out *(see Rule, page* 40*)*.

Ex. 2. Required the course and distance from A to B.

Lat. A	51° 23′ N.	Mer. parts	3606	Long. A	9° 29′ W.
Lat. B	48 23 N.	Mer. parts	3326	Long. B	4 29 W.
	3 0	Mer. diff. lat.	280		5 0
	60				60
Diff. of lat.	180 S.			Diff. of long.	300 E.

Both latitudes being of the *same* name (north), take the *difference* and reduce to miles. Take out the meridional parts for each lat. (Table IV, Norie), and take also the *difference* of these, since the *lats.* are of the *same* name. The longs. being of *like* names the diff. of long. is found by taking the less long. from the greater, which also is reduced to miles.

Diff. long. 300 Log. (+ 10)	12·477121	Course 46° 58′ 30″ Secant	0·166014
Mer. diff. lat. 280 Log.	2·447158	Diff. lat. 180 Log.	2·255273
Tang.	10·029963	Log.	2·421287
Course S. 46° 58′ 30″ E.		Distance 263·8.	

Ex. 3. Required the course and distance from Cape Bajoli to Cape Sicie.

Lat. Cape Bajoli	40° 1′ N.	Mer. parts	2624	Long. Cape Bajoli	3° 48′ E.
Lat. Cape Sicie	43 3 N.	Mer. parts	2867	Long. Cape Sicie	5 51 E.
	3 2	Mer. diff. lat.	243		2 3
	60				60
Diff. of lat.	182 N.			Diff. of long.	123 E.

Diff. long. 123 Log. (+ 10)	12·089905	Course 26° 50′ 50″ Secant	0·049532
Mer. diff. lat. 243 Log.	2·385606	Diff. lat. 182 Log.	2·260071
Tang.	9·704299	Log.	2·309603
Course N. 26° 50′ 50″ E.		Distance 203·9.	

Ex. 4. Required the course and distance from Cape Formosa to St. Helena.

Lat. Cape Formosa	4° 15′ N.	Mer. parts	255	Long. C. Formosa	6° 11′ E.
Lat. St. Helena	15 55 S.	Mer. parts	968	Long. St. Helena	5 45 W.
	20 10	Mer. diff. lat.	1223		11 56
	60				60
Diff. of lat.	1210 S.			Diff. of long.	716 W.

Diff. long. 716 Log. (+ 10)	12·854913	Course 30° 20′ 48″ Secant	0·063997
Mer. diff. lat. 1223 Log.	3·087426	Diff. of lat. 1210 Log.	3·082785
Tang.	9·767487	Log.	3·146782
Course S. 30° 20′ 48″ W.		Distance 1402	

Ex. 5. Required the course and distance from Bahia to Fernando Po.

Lat. Bahia	13° 1′ S.	Mer. parts	788	Long. Bahia	38° 32′ W.
Lat. Fernando Po	3 48 N.	Mer. parts	228	Long. Fernando Po	8 43 E.
	16 49	Mer diff. lat.	1016		47 15
	60				60
Diff. of lat.	1009 N.			Diff. of long.	2835 E.

Diff. long. 2835 Log. (+ 10)	13·452553	Course 70° 17′ Secant	0·471895
Mer. diff. lat. 1016 Log.	3·006894	Diff. of lat. 1009 Log.	3·003891
Tang.	10·445659	Log.	3·475786
Course N. 70° 17′ E.		Distance 2991	

Ex. 6. Required the course and distance from A to B.

Lat. A	44° 44′ S.	Mer. parts	3007	Long. A	148° 39′ W.
Lat. B	55 55 N.	Mer. parts	4065	Long. B	44 44 E.
	100 39	Mer. diff. lat.	7072		193 23
	60				360 0
Diff. of lat.	6039 N.				166 37
					60
				Diff. of long.	9997 W.

Diff. long. 9997	Log. (+ 10)	13·999870	Course 54° 43′ 26″	Secant 0·238435
Mer. diff. lat. 7072	Log.	3·849542	Diff. of lat. 6039	Log. 3·780965
	Tang.	10·150328		Log. 4·019400
Course N. 54° 43′ 26″ W.			Distance 10457	

Ex. 7. Required the course and distance from Cape East, New Zealand, to Cape Horn.

Lat. Cape East	37° 42′ S.	Mer. parts	2445	Long. Cape East	178° 40′ E.
Lat. Cape Horn	55 59 S.	Mer. parts	4072	Long. Cape Horn	67 16 W.
	18 17	Mer. diff. lat.	1627		245 56
	60				360 0
Diff. of lat.	1097 S.				114 4
					60
				Diff. of long.	6844 E.

Diff. long. 6844	Log. (+ 10)	13·835310	Course 76° 37′ 39″	Secant 0·635860
Mer. diff. lat. 1627	Log.	3·211388	Diff. of lat. 1097	Log. 3·040207
	Tang.	10·623922		Log. 3·676067
Course S. 76° 37′ 39″ E.			Distance 4743	

Examples for Practice.

Required the course and distance from A to B in each of the following examples:—

	LATITUDE.	LONGITUDE.		LATITUDE.	LONGITUDE.
1.	A 38° 14′ N.	A 2° 7′ E.	12.	A 35° 14′ S.	A 75° 30′ E.
	B 39 51 N.	B 4 18 E.		B 18 23 S.	B 12 2 E.
2.	A 49 53 N.	A 6 19 W.	13.	A 4 24 N.	A 7 46 W.
	B 48 28 N.	B 5 3 W.		B 8 48 S.	B 13 8 E.
3.	A 53 18 N.	A 0 55 E.	14.	A 57 43 S.	A 10 37 E.
	B 57 58 N.	B 7 3 E.		B 55 35 S.	B 1 28 W.
4.	A 50 4 N.	A 5 42 W.	15.	A 55 40 N.	A 2 25 W.
	B 51 25 N.	B 9 29 W.		B 50 25 N.	B 3 40 E.
5.	A 64 30 N.	A 4 20 W.	16.	A 6 11 N.	A 80 15 W.
	B 60 40 N.	B 0 10 E.		B 6 0 S.	B 39 16 W.
6.	A 46 30 S.	A 8 20 E.	17.	A 55 28 N.	A 1 9 E.
	B 39 20 S.	B 3 10 E.		B 57 58 N.	B 7 3 E.
7.	A 22 55 S.	A 43 9 W.	18.	A 49 56 N.	A 10 19 E.
	B 34 22 S.	B 18 29 E.		B 38 39 N.	B 27 14 E.
8.	A 54 54 S.	A 60 28 W.	19.	A 35 51 S.	A 138 54 E.
	B 34 22 S.	B 18 24 E.		B 38 52 N.	B 165 53 W.
9.	A 45 15 N.	A 35 26 W.	20.	A 15 30 N.	A 176 34 E.
	B 47 10 N.	B 32 15 W.		B 15 30 S.	B 176 34 W.
10.	A 34 22 S.	A 18 29 E.	21.	A 22 22 S.	A 122 22 W.
	B 15 55 S.	B 5 43 W.		B 33 33 N.	B 111 11 E.
11.	A 49 57 N.	A 5 12 W.	22.	A 17 0 N.	A 180 0 E.
	B 36 58 N.	B 25 12 W.		B 20 0 N.	B 161 0 E.

To find the latitude and longitude in, having given the latitude from, the longitude from, and the course and distance between the two places by Traverse Table and meridional parts.*

RULE XXXVII.

1°. *With given* course *and* distance *enter the Traverse Table and take out the corresponding* true difference of latitude, *from which and* latitude from, *find* latitude in *and then* meridional difference of latitude, *as in* Rule XXI, page 52.

2°. *At the given* course *look in the column of the* true difference of latitude *for the* meridional difference latitude; *the corresponding* departure *will be the* difference of longitude, *from which and the* longitude from *find the* longitude in, *as in* Rule XXV, page 56.

EXAMPLES.

Ex. 1. A ship from lat. 55° 1′ N., long. 1° 25 W., sails S.S.E. ½ E., 246 miles: required the lat. in and long in.

Entering Traverse Table II. with course S. 2½ points E., and distance 246, we obtain diff. lat. 217·0, and dep. 116·0.

6,0)21,7	Lat. left	55° 1′ N.	Mer. parts	3970	Rule XXI, page 52.
3° 37′		3 37 S.	Mer. parts	3607	
	Lat. in	51 24 N.	Mer. diff. lat.	363	
			½ mer. diff. lat.	181·5	

The course 2½ points, and half mer. diff. lat. 181·5 (in diff. lat. column), the nearest found in the Table is 181·7, the corresponding departure is 97·1, which multiplied by 2 (having divided mer. diff. lat. by 2), gives diff. long 194·2 miles.

6,0)19,4·2	Long. left	1° 25′ W.	The ship being 1° 25′ W., or 85′
3° 14′		3 14 E.	West of Greenwich, must evidently
			be in East longitude, after having
	Long. in	1 49 E.	sailed 194 miles to the Eastward.

Ex. 2. A ship from lat. 42° 36′ S., long. 178° 43′ E., sails S.E. ¾ E., 299 miles find lat. in and long. in.

Course 4¾ points, and dist. 299, give diff. lat. 178·1, dep. 240·2.

6,0)17,8·1	Lat. left	42° 36′ S.	Mer. parts	2830
2° 58′		2 58 S.	Mer. parts	3078
	Lat. in	45 34 S.	Mer diff. lat.	2)248
				124

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* The general method of solution by "meridional parts," is from the formulæ—

$$\text{True diff. lat.} = \text{dist.} \times \cos.\text{ course}$$

$$\therefore \log.\ \textit{true diff. lat.} = \log.\text{ dist.} + \log.\cos.\text{ course} - 10$$

$$\text{Diff. long.} = \text{mer. diff. lat.} \times \text{tang. course}$$

$$\therefore \log.\ \textit{diff. long.} = \log.\text{ mer. diff. lat.} + \log.\text{ tang. course} - 10.$$

Course $4\frac{3}{4}$ points, and half mer. diff. lat. 124 (in diff. lat. column), gives in dep. column 167·1, which doubled is 334·2, the diff. long.

6,0)33,4·2	Long. left	178° 43′ E.
		5 34 E.
5° 34′		184 17 E.
		360 0
	Long. in	175 43 W.

Ex. 3. From lat. 50° 48′ N., and long 1° 10′ W., sailed S. 41° E., 275 miles: required the lat. in and long. in.

In the Traverse Table at the distance 275, and *course* 41°, the corresponding *true diff. lat.* is 207·5, or 3° 27′·5, which being subtracted from 50° 48′ N., the *lat. in* is 47° 20′·5 N.; taking out the *mer. parts* for 50° 48′, and 47° 20′·5, the *mer. diff. lat.* is found to be 317, to *half* which as a *true diff. lat.*, and the course 41°, the *dep.* is 137·8, twice which is 275·6, that is, the *diff. long.* is 4° 36′ E.: hence the long. in is 3° 26′ E.

Ex. 4. From lat. 50° 30′ N., and long 37° 55′ W., sailed S.W. $\frac{3}{4}$ S., until arrived at lat. 52° 15′ N.

Lat. from 50° 30′ N.	Mer. parts 3521	Course $3\frac{1}{4}$ points, and mer. diff. lat. in diff. lat. column, give in *dep.* column 125·4, which is the diff. long.	
Lat. in 52 15 N.	Mer. parts 3690		
	Mer. diff. lat. 169	Long. left	37° 55′ W.
	6,0)12,5·4		2 5 W.
	2° 5′	Long. in	40 0 W.

REMARKS ON MIDDLE LATITUDE AND MERCATOR'S SAILING.

"The difference of longitude found by middle latitude is true at the equator, and very nearly true for short distances in all latitudes, especially when the course is E. or W. In high latitudes, when the distance is great and the course oblique, the error becomes considerable; but the result may be made as accurate as we please by sub-dividing the distance run into small portions, and finding the difference of longitude for each portion separately. The difference of longitude deduced by middle latitude sailing is too small: an estimate of the error for places on the same side of the equator may be formed by the help of a few cases. Suppose the course 4 points or 45°, and the difference of latitude 10° or 600; then if this difference of latitude is made good in any latitude below 30°, the error of the difference of longitude will not exceed 2′; if made good below the parallels of 40° and 50°, the error will be about 3′; and between 60° and 70° about 19′, or $\frac{1}{3}$ of a degree. For smaller distances the errors will be much less, and for greater distances much greater, as they vary in much more rapid proportion than the distances. It has been observed before that when the course is large, the difference of longitude should be found by middle latitude in preference to Mercator's Sailing; because, although the latter is mathematically correct in principle, yet a small error in the course may, when the course is large, produce a considerable error in the difference of longitude. The reason of this is easily shown. In middle latitude sailing we convert the *departure* into difference of longitude. The process increases the departure in a proportion which is less than 2 to 1 in all latitudes below 60°; and exceeds 3 to 1 in all latitudes beyond 70°. The error of the departure, increased in the same proportion, becomes thus the error of difference of longitude. Now when the course is nearly E. or W., the departure is nearly the same as the distance, and an error of some degrees in the course does not affect the departure sensibly; hence in this case the error of the difference of longitude depends on that of the distance alone. But in Mercator's Sailing, on the other hand, we convert the *meridional difference of latitude* into difference of longitude, and the process, when the course is large, converts a given meridional difference of latitude into a difference of longitude much greater than itself; and thus increases the error of the meridional difference of latitude in the same proportion. Thus, for example, at the course 80°, the difference of longitude exceeds the meridional difference of latitude in the proportion of 6 to 1; at the course 86° this proportion is 11 to 1. Now when the course is large, a slight change in it sensibly affects the difference of latitude and also the meridional difference of latitude, which is deduced directly from it. In high latitudes the meridional parts vary rapidly, and the error of difference of longitude is aggravated accordingly; hence the precept more especially demands attention in high latitudes."—*Raper's Practice of Navigation, pp.* 103—104.

THE DAY'S WORK.

THIS is the process of *finding the ship's place at noon*—that is, its latitude and longitude, having given the latitude and longitude at the noon preceding, or a departure taken since, the compass courses and distances run in the interval, the leeway (if any), variation and deviation (if any), direction and rate of current (if any), &c., &c.

RULE XXXVIII.*

1°. *Correct each* course *for* leeway *and* variation (see Rules XXVI to XXIX, pages 58 to 66), *which arrange in the tabular form as in the example following.* Add *together the* hourly distances *sailed on each* course, *and insert the same in the table, opposite the true course.*

(a) *When a departure has been taken, consider the* opposite to the bearing *as a* course, *which correct for* variation, *and insert in the table as an actual* course, *with the* distance *of the object as a* distance. *The* departure course *is generally put down in the table as the* first course.

(b) *The* set *of a current is to be corrected for* variation, *and inserted in the table as a* course; *the* drift *being taken as a* distance. *The* current course *is generally inserted in the table as the* last course.

2°. *Take out of the Traverse Tables* (Table I or II, Raper or Norie) *the* difference of latitude *and* departure *to each* course *and* distance (see page 75), *and proceed to find the* difference of latitude *and* departure *made good as directed in* Rule XXXII, page 78, *Traverse Sailing.*

3°. *Find the* course *and* distance *made good,* see Rule XXXVI, page 89.

4°. *Find the* latitude in *by applying the* difference of latitude *to the* latitude from.

If a departure has been taken, the difference of latitude is to be applied to latitude of the point of land; if otherwise, to yesterday's latitude.

5°. *To find the* difference of longitude *by* Middle Latitude Sailing.

(c) *Find the middle latitude as directed,* Rule XXIII, page 54.

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* Nearly the entire process of computing the Day's Work has already been given, and if the learner has thoroughly mastered the rules laid down in the preceding pages, he will find no difficulty in working the Day's Work without reference to them.

(d) *Next at the page of Traverse Table on which the* degrees *(at top or bottom) corresponds to* middle latitude, *find the* departure *in a* difference of latitude *column, then the corresponding* distance *is the* difference of longitude.

When the latitude left and latitude in are of *contrary* names, no sensible error can arise from taking the departure itself as the difference of longitude.

6°. *To find the* difference of longitude *by* Parallel Sailing.

If the ship has made a due E. or due W. course good, the difference of longitude is found thus:—

(e) *With the latitude as a course and the departure in a* difference of latitude *column, then the corresponding* distance *is the* difference of longitude (Rule XXXIV, page 84).

7°. *To find the* difference of longitude *by* Mercator's Sailing.

(f) *Find meridional difference of latitude,* see Rule XXI, page 52.

(g) *Then with* course *and* meridional difference of latitude *(in a* latitude *column) find the corresponding* departure, *which is the* difference of longitude (see Rule XXXVII, page 92).

When the course is less than 5 points or 56°, the difference of longitude may be found by either or both *Middle Latitude* or *Mercator's* method, but if the course exceeds 5 points, the method of *Middle Latitude* should be used in preference to *Mercator's* (see *Remarks* in page 94).

8°. *With the* longitude left *and* difference of longitude *find the* longitude in (see Rule XXV, page 56).

When a departure has been taken the longitude left is that of the point of land otherwise that of yesterday.

Remark.—It will effect a considerable saving of time and trouble, more especially when the variation is given in degrees, to correct the compass courses for leeway only; then with these courses and the distances run on each, to proceed to find difference of latitude and departure, and thence the course (magnetic) and distance made good. Allow the variation upon this *magnetic* course, and so get the true course; with which, and distance made good, find the *true* difference of latitude and departure.

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	S.S.E. ½ E.	4	2	East.	2	A point of land in lat. 42° 12′ S., long. 42° 58′ W., bearing by compass E. by N. ½ N., distance 21 miles.
2		4	3			
3		5	0			
4		5	2			
5		4	0			
6	N.N.E.	4	1	Ditto.	2¼	
7		3	8			
8		3	5			
9		3	2			
10	S.W. ½ W.	3	5	W.N.W.	1¾	
11		3	6			Variation 1¾ West.
12		4	0			
1		4	2			
2	N. ½ E.	4	3	Ditto.	2½	
3		4	4			
4		4	5			
5	S.S.W.	6	2	West.	½	
6		6	4			A current set by compass W.S.W., 26 miles from the time the departure was taken to the end of the day.
7		6	2			
8		6	5			
9	N. by W. ½ W.	6	2	Ditto.	¾	
10		5	7			
11		5	3			
12		5	4			

Correct the courses for variation and leeway, and find the course and distance from the given point, and the latitude and longitude in by inspection.

Courses.	Dist.	N.	S.	E.	W.
S. 4¾ W.	21		12·5		16·9
S. 2¼ E.	22·7		20·5	9·7	
N. 2 W.	14·6	13·5			5·6
S. 1 W.	15·3		15·0		3·0
N. 1 E...	13·2	13·0		2·6	
S. ¼ E.	25·3		25·3	1·2	
N. 2½ W.	22·6	19·9			10·7
S. 4¼ W.	26		17·5		19·3
		46·4	90·8	13·5	55·5
			46·4		13·5
			44·4		42·0

Difference latitude 44·4 } give in Table II { Course S. 43° W.*
Departure ...... 42·0 } { Distance 61 miles.

Latitude left	42° 12′ S.	Meridional parts	2798
Diff. latitude	44 S.	Meridional parts	2858
Latitude in	42 56		60
Sum 2)85	8		
Middle lat.	42 34		

* The course being less than 56°, the difference of longitude may be found both by middle latitude and Mercator's method.

Course S. 43° W. } give in Table II { Difference of longitude 55′·9
Mer. diff. lat. 60 } (in departure column.)
Mid. latitude 42½° } give in Table II { Difference of longitude 57′
Dep. 42·0 (as d. lat.) } (in distance column.)

Longitude left	42° 58′	W.
Diff. longitude	56	W.
Longitude in	43 54	W.

(1.) To correct the courses (see Rule XXIX, page 66):—

The Departure Course.

The opposite point to E. by N. ½ N. is W. by S. ½ S.

W. by S. ½ S. = 6½ R. of S.
Variation 1¾ L.

True course 4¾ R. of S.
Or S.W. ¾ W. Dist. 21′.

This is inserted in Traverse Table as 1st course.

1st Course S.S.E. ½ E.

S.S.E. ½ E. = 2½ L. of S.
Leeway 2 R. } ¼ R.
Var. 1¾ L. }

True course 2¼ L. of S.
Or S.S.E. ¼ E.

The distance, 22′·7, is found by adding up the hourly distances until the course is altered at 6 o'clock. Insert this course and distance in Table as 2nd course.

2nd Course N.N.E.

N.N.E. = 2 pts. R. of N.
Leeway 2¼ L. } 4 L.
Var. 1¾ L. }

True course 2 L. of N.
Or N.N.W.

The distance, 14·6, is found by adding up the hourly distances from 6 o'clock until the course is changed at 10.

3rd Course S.W. ½ W.

S.W. ½ W. = 4½ pts. R. of S.
Leeway 1¾ L. } 3½ L.
Var. 1¾ L. }

True course 1 R. of S.
Or S. by W.

Distance, 15′·3, is found by adding up hourly distances from 10 o'clock until 2.

4th Course N. ¼ E.

N. ¼ E. = ¼ R. of N.
Leeway 2½ R. } ¾ R.
Var. 1¾ L. }

True course 1 R. of N.
Or N. by E. Distance 13′·2.

5th Course S.S.W.

S.S.W. = 2 R. of S.
Leeway ½ L. } 2¼ L.
Var. 1¾ L. }

True course ¼ L. of S.
Or S ¼ E. Distance 25′·3.

6th Course N. by W. ½ W.

N. by W. ½ W. = 1½ L. of N.
Leeway ¾ R. } 1 L.
Var. 1¾ L. }

True course 2½ L. of N.
Or N.N.W. ½ W. Distance 22′·6.

Current Course W.S.W.

W.S.W. = 6 R. of S.
Variation 1¾ L.

4¼ R. of S.
Or S.W. ¼ W., 26′.

Previously to opening the Traverse Table to take out the difference of latitude and departure to each course and distance in the above table, fill up the columns not wanted: thus, in the first course, S. 4¾ W., the S. and W. will be wanted, and the

N. and E. will not be wanted; fill up these last two columns by drawing a dash under N. and E. Proceed in the same manner with the other courses.

(2.) *To find the difference of latitude and departure* to each course and distance by the Traverse Table.

Enter Traverse Table, and take out the difference of latitude and departure corresponding to $4\frac{3}{4}$ points, and distance 21′. Insert them in the columns S. and W.

The second course is $2\frac{1}{4}$ points, and the distance 22′·7. Then $2\frac{1}{4}$ points and distance 227 (omitting the decimal point), give difference of latitude 205·2, departure 97·1; now dropping the tenths in each—namely, the 2 and the 1—and shifting the decimal point one place to the left, we have difference of latitude 20·5, departure 9·7, which insert in columns S. and E., the course being marked S. and E.

The third course is N. 2 W., and distance 14·6. Look for 2 points and distance 146, which give difference of latitude 134·9, departure 55·9; now dropping the tenths, the 9 and the 9, and increasing the preceding figure by 1, as the tenths exceed 5, we have, by removing the decimal point one figure to the left, the difference of latitude 13·5, and departure 5·6.

Proceed in this way with the remaining courses.

Next, we find the sum of the four columns, when it appears the ship has sailed 46·4 N., and 90·8 S.; therefore upon the whole the difference of latitude is 44·4 S. The sum of the eastings is 13·5, of the westings 55·5, and the departure made good is 42·0 W.

(3.) *To find the Course and Distance made good.*—The difference of latitude 44·4, and departure 42·0, found to correspond in their columns, give course S. 43° W., distance 61 miles (see page 77).

(4.) We next apply the difference of latitude, 44′ S., to the latitude left, 42° 12′ S. (the latitude of point of land), taking the sum, as they are of one name, and the latitude 42° 56′ S., takes the name of either (Rule XXII, page 53).

(5.) *To find the Difference of Longitude.*—Take out the meridional parts for latitude left, 42° 12′, and also for latitude in 42° 56′, and take the less from the greater, as the latitudes are of one name. The remainder is meridional difference of latitude (Rule XXI, page 52).

Or, find middle latitude by adding together latitude left and latitude in, and divide the sum by 2; the quotient is the middle latitude (Rule XXIII, page 54).

Then the course 43°, in Table II, and meridional difference of latitude 60′, found in difference of latitude column, gives in departure column 55′·9, or difference of longitude 56′ (Rule XXXVII, page 93).

Or, the middle latitude $42\frac{1}{2}$°, in Table II, and departure 42′·0, in difference of latitude column, gives in distance column 57′, the difference of longitude (Rule XXXV, page 86).

The difference of longitude 56′ W. (that found by Mercator's sailing), added to longitude left 42° 58′ W., gives longitude in 43° 54′ W. (Rule XXV, page 56).

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	E.N.E.	7		N.N.W.	0	A point, Cape Runaway, latitude 37° 31′ S., longitude 178° 21′ E., bearing by compass S.W. ¾ S., distance 15 miles.
2		7	5			
3		7	8			
4		7	7			
5	E. by N.	6		N. by E.	½	
6		6	5			
7		6	7			
8		6	8			
9	E.S.E.	6		N.E.	1	
10		5	8			
11		5	8			Variation 1¼ point East.
12		5	4			
1	E. by N.	5		S.E. by S.	1¼	
2		5	6			
3		5	4			
4	N.E. by E.	5		S.E. by E.	1½	
5		4				
6		4	6			A current set by compass S.S.W. ½ W., 7 miles from the time the departure was taken to the end of the day.
7		4	6			
8		4	8			
9	N.E. ½ E.	4		E.S.E.	2¼	
10		3	8			
11		3	8			
12		3	4			

Courses.	Dist.	N.	S.	E.	W.
N. 4½ E.	15	9·6		11·6	
N. 7¼ E.	30	4·4		29·7	
S. 7¼ E.	26		3·8	25·7	
S. 3¾ E.	23		17·0	15·4	
N. 7 E.	16	3·1		15·7	
N. 4¾ E.	23	13·7		18·5	
N. 3½ E.	15	11·6		9·5	
S. 3¾ W.	7		5·2		4·7
		42·4	26·0	126·1	4·7
		26·0		4·7	
		16·4		121·4	

Diff. lat. 16·4, and dep. 121·4, give course N. 82° E., dist. 123 miles (see page 77).

Lat. left 37° 31′ S.
Diff. lat. — 16 N.

Lat. in 37 15 S.

2)74 46

Mid. lat. 37 23

See Rule XXIII, page 54.

Mid. lat. 37° as course, and dep. 121·4, in diff. lat. column, give diff. long. 152 in distance column.

6,0)15,2

2° 32′

Long. left 178° 21′ E.
Diff. long. 2 32 E.

Long. in 180 53 E.
360 0

Or, 179 7 W.

See Note, Rule XXV, page 56.

H.	Courses.	K	1/10	Winds.	Lee-way.	Remarks, &c.
1	E. by N.	7	2	S.E. by S.	¼	A point, Tynemouth Light in latitude 55° 1′ N., longitude 1° 25′ W., bearing by compass W. by N. ½ N., distance 15 miles.
2		7	2			
3		7	4			
4		7	2			
5	E.S.E.	6	6	South	½	
6		6	5			
7		6	4			
8		6	5			
9	N.E. by E.	5	2	S.E. by E.	1	
10		5	3			
11		5	3			Variation 2¼ points West.
12		5	2			
1	S.S.E.	5		East.	1¼	
2		5				
3		5				
4		5				
5	S.E. by S.	3	8	E. by N.	2	
6		3	6			A current set by compass S.S.W. ½ W., 18 miles from the time the departure was taken to the end of the day.
7		3	4			
8		3	2			
9	E.S.E.	3	4	N.E.	2¼	
10		3	6			
11		3	5			
12		3	5			

Courses.	Dist.	N.	S.	E.	W.
N. 7¼ E.	15	2·2		14·8	
N. 4¾ E.	29	18·4		22·4	
N. 7¼ E.	26	3·8		25·7	
N. 1¾ E.	21	19·8		7·1	
S. 3 E.	20		16·6	11·1	
S. 3¼ E.	14		11·2	8·3	
S. 6 E.	14		5·4	12·9	
S. ½ W.	18		18·0		0·9
		44·2	51·2	102·3	0·9
			44·2	0·9	
			7·0	101·4	

Diff. lat. 7·0, and dep. 101·4, give (in Table II) course S. 86° E., dist. 102 miles.*

Lat. left	55° 1′ N.	
Diff. lat.	— 7 S.	
Lat. in	54 54 N.	
Sum	2)109 55 N.	
Mid. lat.	54 57	

See Rule XXIII, page 54.

The mid. lat. 55° as course, and dep. 101·4, in diff. lat. column, give in the dist. column 177 miles, which is the diff. of long. (see Rule XXXV, page 86.)

Long. left	1° 25′ W.
Diff. long.	2 57 E.
Long. in	1 32 E.

Rule XXV, page 56.

* The course being above 5 points, the difference of longitude is found by Middle latitude method in preference to Mercator's, see Note (g), page 96.

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	N.N.E.	4	5	E.	½	A point in lat. 43° 47′ N., long. 7° 51′ W., bearing by compass S.W. by S., distance 10 miles.
2		5	5			
3		5	6			
4		4	4			
5	N.E.	3	6	E.S.E.	¾	
6		4	4			
7		5				
8		5				
9	E.S.E.	6		S.	2	
10		7				
11		6	4			Variation 2¼ points West.
12		5	6			
1	W.	5		S.S.W.	1½	
2		5	6			
3		5	4			
4		6				
5	S.S.E.	5	6	S.W.	½	
6		6				A current set by compass N. by W., 12 miles from the time the departure was taken to the end of the day.
7		6	4			
8		7				
9	N.N.W.	6	5	W.	1	
10		6	4			
11		6	5			
12		7	2			

Courses.	Dist.	N.	S.	E.	W.
N. ¾ E.	10	9·9		1·5	
N. ¾ W.	20	19·8			2·9
N. 1 E.	18	17·7		3·5	
N. 5¾ E.	25	10·7		22·6	
N. 7¼ W.	22	3·2			21·8
S. 4¾ E.	25		14·9	20·1	
N. 3¼ W.	26·6	21·4			15·9
N. 3¼ W.	12	9·6			7·1
		92·3	14·9	47·7	47·7
		14·9		47·7	
		77·4		0·0	

Lat. left	43° 47′ N.			Long. left	7° 51′ W.
Diff. lat.	1 17 N.				
Lat. in	45 4 N.			Long. in	7 51 W.

The East and West departures being of equal value they destroy one another, and the ship has made no departure; she is under the same meridian as she sailed from, the course is due North, and the distance sailed is equal to the difference of latitude.

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1						
2	N.N.W.	8		N.E.	1	I take my departure from an Island in lat. 0° 15′ S., long. 170° 44′ E., bearing by compass N.E. ½ E., 21 miles.
3		8	4			
4		7	6			
5	E.S.E.	6	2	Ditto.	1½	
6		5	8			
7		5	4			
8		5	2			
9		5	4			
10	E. by N.	3	4	N. by E.	2	
11		4				
12		4	4			Variation ¾ point East.
1		5	8			
2		5	4			
3	N. by W. ¾ W.	5	3	N.E.	1½	
4		5	7			
5		6				
6		7				A current set by compass N. by E., 18 miles, from the time of taking the departure till the end of the day.
7		6				
8	N.W.	5	6	Ditto.	1¾	
9		5	4			
10		5	7			
11		5	3			
12		5				

Courses.	Dist.	N.	S.	E.	W.
S. 5¼ W.	21		10·8		18·0
N. 2¼ W.	24	21·7			10·3
S. 3¼ E.	28		20·7	18·8	
S. 6¼ E.	23		7·7	21·7	
N. 2¼ W.	30	26·5			14·1
N. 5 W.	27	15·0			22·4
N. 1¾ E...	18	16·9		6·1	
		80·1	39·2	46·6	64·8
		39·2			46·6
		40·9			18·2

Diff. lat. 40·9, and dep. 18·2, give course N. 24° W., dist. 45 miles.

Lat. left 0° 15′ S.	Mer. parts 15	Long. left 170° 44′ E.
Diff. lat. 0 41 N.	Mer. parts 26	Diff. long. — 18 W.
Lat. in 0 26 N.	41	Long. in 170 26 E.

Course 24°, and mer. diff. lat. 41, in diff. lat. column, give diff. long. 18·3, in dep. column. Or, since the lat. left and lat. in being of contrary names, the dep. itself may be taken as the diff. long. (see (d), Note, page 96.)

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	N.E. ½ E.	6		N.N.W.	2¼	A point of land, in lat. 47° 35′ S., long. 179° 26′ E., bearing by compass W.S.W. distance 18 miles.
2		6	2			
3		5	6			
4		6	4			
5	N.E. by E. ½ E.	5	7	S.E. ½ E.	2¼	
6		5	8			
7		5	9			
8		5	9			
9	S.E. ¾ E.	5	6	N.E. by N.	0	
10		5	4			
11		5	3			Variation 2¼ points East.
12		5	2			
1	South.	4	7	E.S.E.	2	
2		4	8			
3		4	9			
4		4	9			
5	N.W. by W. ½ W.	4	2	S.W. ½ W.	1¾	A current set by compass N.E. by E. ¾ E., 36½ miles from the time the departure was taken to the end of the day.
6		4	3			
7		4	5			
8		4	6			
9	N.W. ½ W.	2	6	S.W. by W. ½ W.	2¼	
10		2	5			
11		2	4			
12		2	3			

Courses.	Dist.	N.	S.	E.	W.
S. 7¾ E.	18		0·9	18·0	
S. 7 E.	24·2		4·7	23·7	
N. 5¼ E.	23·3	11·0		20·6	
S. 2¾ E.	21·5		19·0	10·1	
S. 4¼ W.	19·3		13·0		14·3
N. 1½ W.	17·6	16·8			5·1
North	9·8	9·8			
East	36·5			36·5	
		37·6	37·6	108·9	19·4
		37·6		19·4	
		0·0		89·5	

Course East. Distance 89·5 miles.*

Lat. left 47° 35′ S.

Lat. in 47 35 S.

Lat. in 47½° as course, and dep. 89·5, gives us 132 miles diff. of long. (see Rule XXXIV, page 84.)

Long. left	179° 26′	E.
Diff. long.	2 12	E.
Long. in	181 38	E.
	360 0	
Or,	178 22	W.

* The sum of the northings and southings are both 37·6, and being of contrary directions, show that the ship has returned to the same parallel of latitude which she sailed from. The *course* is due *East*, and the *distance*, 89·5, the same as the departure.

H.	COURSES.	K	$\frac{1}{10}$	WINDS.	LEE-WAY.	REMARKS, &c.
1	N.W. ½ W.	3	5	N. by E. ½ E.	1¾	A point, Cape Swaine, in latitude 52° 15′ N., longitude 128° 30′ W., bearing by compass E. by N. ½ N., distance 16 miles.
2		3	6			
3		3	2			
4	E. ¼ S.	4		N.N.E. ½ E.	2	
5		4	2			
6		4	3			
7		4	5			
8		4	6			
9	S. by E. ¾ E.	5	2	S.W.	2½	
10		5				
11		5	3			
12		5	6			
1	W. by N. ¾ N.	3	6	Ditto.	2¾	Variation 2¼ points East.
2		3	4			
3		3	3			
4		3	4			
5	S. ¼ E.	4	6	S.W. by W. ½ W.	2¼	
6		4	7			
7		5				
8		5	2			
9	N.W.	6		W.S.W.	1¼	A current set by compass E. by S. ¾ S., 20 miles, from the time the departure was taken to the end of the day.
10		5	8			
11		5	4			
12		5	3			

COURSES.	DIST.	N.	S.	E.	W.
N. 7¼ W.	16	2·3			15·8
N. 4 W.	10·3	7·3			7·3
S. 3½ E.	21·6		16·7	13·7	
S. 2 E.	21·1		19·5	8·1	
N. 1¼ W.	13·7	13·3			3·3
S. ¼ E.	19·5		19·5	1·0	
N. ½ W.	22·5	22·4			2·2
S. 4 E.	20		14·1	14·1*	
		45·3	69·8	36·9	28·6
			45·3	28·6	
			24·5	8·3	

Diff. of lat. 24·5, and dep. 8·3, give course S. 19° E., and distance 26 miles.*

Lat. left	52° 15′ 0″ N.	Mer. parts	3690
Diff. lat.	— 24 30 S.	Mer. parts	3650
Lat in	51 50 30 N.		40
	2)104 5		
Mid. lat.	52 2		

* The course being less than 56°, the diff. of long. may be found both by middle latitude and Mercator's method.

The course S. 19° E., and mer. diff. lat. 40, in lat. column, gives dep. 13′·7, which is the required diff. of long. (see Rule (g), page 96.) Or, mid. lat. 52° as course, and dep. 8′·3 (8·0 and 8·6) give diff. of long. 13½′ in dist. column (Rule XXXIV, page 84).

Long. Cape Swaine	128° 30′ W.
Diff. of long.	— 14 E.
Long. in	128 16 W.

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	N. ½ W.	5	4	W. by N.	1¾	A point in lat. 54° 30′ N., long. 60° 0′ W., bearing by compass W. by N. ½ N., distance 14 miles.
2		5	4			
3		5	3			
4		5				
5	S.W. ½ S.	2	5	Ditto.	2¾	
6		2	5			
7		2	7			
8	N.N.E. ½ E.	3	6	N.W. ½ N.	2½	
9		3	5			
10		3	4			
11		3	7			
12		3	8			Variation 3¾ points West.
1	W. ½ N.	4	2	N.N.W.	2¼	
2		4	4			
3		4	5			
4		4	6			
5	S. E. ½ E.	6	5	S. by W. ½ W.	½	
6		6	4			
7		6				
8		5	8			
9	S. ½ W.	1	4	S.E. by E.	3	A current set by compass N.W. ½ W., 22½ miles, from the time the departure was taken to the end of the day.
10		1	3			
11		1	3			
12		1				

Courses.	Dist.	N.	S.	E.	W.
N. 5¾ E.	14	6·0		12·7	
N. 2½ W.	21·1	18·6			10·0
S. 3 E.	7·7		6·4	4·3	
N. 1¼ E.	18	17·5		4·4	
S. 2½ W.	17·7		15·6		8·3
N. 7¼ E.	24·7	3·6		24·4	
S. ¼ E.	5		5·0	0·2	
S. 7¾ W.	22·5		1·1		22·5
		45·7	28·1	46·0	40·8
		28·1		40·8	
		17·6		5·2	

Diff. lat. 17·6, dep. 5·2, give course N. 16½° E., distance 18 miles.*

Lat. left	54° 30′ N.	Mer. parts	3916	
Diff. lat.	18 N.	Mer. parts	3947	
Lat. in	54 48 N.		31	
	2)109 18			
Mid. lat.	54 39			

Course 16½°, and mer. diff. lat. 31, give in dep. column the diff. of long. 9 miles: or mid. lat. as course and dep. 5·2, in diff. lat. column give in dist. column 9′, the diff. long.

Long. left	60° 0′ W.
Diff. long.	9 E.
Long. in	59 51 W.

* The diff. of long. may be found both by middle latitude and Mercator's method.

[1]

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	W. by N.	6	2	E.S.E.	0	A point, Lizard, in latitude 49° 58′ N., longitude 5° 12′ W., bearing by compass N.E. by N., distance 12 miles.
2		6	3			
3		6	4			
4		6	1			
5	W.S.W.	5	6	S.	½	
6		5	5			
7		5	5			
8		5	4			
9	W.N.W.	5		S.W.	1	
10		4	8			
11		4	6			
12		4	6			
1	S.W.	4		W.N.W.	1¼	Variation 2¼ points West.
2		4				
3		4	2			
4		3	8			
5	SW. by W.	3	6	N.W. by W.	1¾	
6		3	4			
7		3				
8		3				
9	S.	3	3	W.S.W.	2¼	A current set by compass N.W. ¾ W., 6 miles, from the time the departure was taken to the end of the day.
10		3	3			
11		3	2			
12		3	2			

[2]

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	N.N.W.	3	4	N.E.	1	A point in lat. 55° 40′ S., long. 179° 58′ W., bearing by compass N.E., distance 18 miles.
2		3				
3		2	6			
4		3				
5	E.S.E.	5	2	Ditto.	1½	
6		3	4			
7		4	4			
8		5				
9	E. by S.	3	6	N.E. by N.	2	
10		2	4			
11		4				
12		4				
1	N. by W. ½ W.	4	6	N.E.	1½	Variation 1½ point East.
2		4	6			
3		5	4			
4		3	4			
5	N.N.W.	5	4	Ditto.	1¾	
6		4				
7		3	6			
8		4				
9	N. by W. ½ W.	3	6	N.E. ½ N.	1½	A current set by compass N. by E., 18 miles, from the time the departure was taken to the end of the day.
10		4	4			
11		4				
12		5				

[3]

H.	Courses.	K	$\frac{1}{10}$	Winds.	Leeway.	Remarks, &c.
1	E.	5	3	S.S.E.	$\frac{3}{4}$	A point, Flambro' Head, latitude 54° 7′ N., longitude 0° 5′ W., bearing by compass N.W. by W., distance 17 miles.
2		5	6			
3		5	3			
4	S.E. by E.	6		S. by W.	$\frac{1}{2}$	
5		6	2			
6		6	1			
7	E. $\frac{1}{2}$ S.	4	7	S. by E. $\frac{1}{2}$ E.	$1\frac{1}{4}$	
8		4	6			
9		4	3			
10	S. by W.	3	9	S.E. by E.	2	
11		3	8			
12		3	6			
1		3	5			Variation $2\frac{1}{4}$ points West.
2	S.	2	4	E.S.E.	$2\frac{1}{2}$	
3		2	4			
4		2	4			
5	S.E. by S.	2	5	E. by N.	$2\frac{3}{4}$	
6		2	5			
7		2				
8	E.N.E.	2	2	S.E.	$3\frac{1}{4}$	
9		2	1			A current set by compass N.N.E., 6 miles, from the time the departure was taken to the end of the day.
10		2				
11		2				
12		2				

[4]

H.	Courses.	K	$\frac{1}{10}$	Winds.	Leeway.	Remarks, &c.
1	W.S.W.	4	6	N.W.	$\frac{3}{4}$	A point in lat. 37° 3′ N., long. 9° 0′ W., bearing by compass E. by N $\frac{1}{2}$ N., distance 14 miles.
2		5	4			
3		5	5			
4		6	5			
5	W. by N.	6		N. by W.	$1\frac{1}{4}$	
6		5	5			
7		5	5			
8		5				
9	N.N.W.	5	4	N.E.	$\frac{1}{2}$	
10		5	6			
11		6				
12		6				
1	N.	5		W.N.W.	$\frac{3}{4}$	Variation 2 points West.
2		4	6			
3		4	4			
4		4				
5	S.W.	4	2	Ditto.	$1\frac{3}{4}$	
6		4	6			
7		5	2			
8		5				
9	W. by S.	5	4	S. by W.	$1\frac{1}{4}$	A current set by compass N. by E., 20 miles, from the time the departure was taken to the end of the day.
10		5	4			
11		5				
12		5	2			

[5]

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	N.N.W. ½ W.	3	5	N.E.	1¾	A point in lat. 29° 59′ N., long. 32° 54′ E., bearing by compass N.N.E. ½ E., distance 15 miles.
2		4	1			
3		4	3			
4	E.S.E.	2	7	Ditto.	2	
5		3				
6		3	2			
7		4				
8	S. ¾ E.	5	6	E.S.E.	2¼	
9		5	2			
10		5	5			
11		4	5			
12		4	6			
1	N.E. ½ N.	4	7	Ditto.	1½	Variation 2¼ points West.
2		4	2			
3		4	4			
4		3	7			
5		3	2			
6	W. ½ N.	3	5	S.S.W. ½ W.	1¼	
7		4	2			
8		3	6			
9		3	4			
10	N. by E.	8	5	E. by N.	¼	A current set by compass N.E., 3½ miles an hour for the last 6 hours.
11		9	3			
12		9	2			

[6]

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	S.E. by E.	3	2	S. by W.	2½	A point in lat. 62° 9′ S., long. 140° 17′ E., bearing by compass S.S.W. ½ W., distance 25 miles.
2		3	4			
3		2	8			
4	W. by S.	4	4	Ditto.	1¾	
5		4	5			
6		4	6			
7	S.S.W.	4	3	W.	2	
8		4	3			
9		4	5			
10	N.N.W.	3	4	Ditto.	2¾	
11		3	4			
12		3	2			
1		2	8			Variation 2¾ points East.
2	N.N.E. ½ E.	2	4	E.	3¼	
3		2				
4		1	8			
5		1	6			
6	S.S.E.	2	4	Ditto.	3	
7		2	2			
8		2	4			
9	E.	1	4	N.N.E.	3½	
10		1	4			A current set by compass S. ¾ W., 3 miles an hour for 7½ hours.
11	N.W.	1	2	Ditto.	4	
12		1	2			

[7]

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	W.N.W.	6	3	S.W.	1	A point, Butt of Lewis, in latitude 58° 29′ N., longitude 6° 12′ W., bearing by compass S.E. by S., distance 15 miles.
2		6	3			
3		6	2			
4		6	2			
5	S.W. by W.	6	2	N.W. by W.	1¼	
6		5	8			
7		5	6			
8		5	4			
9	W. by N.	5	2	N. by W.	1½	
10		4	8			
11		4	6			
12		4	4			
1	N. by W.	3	2	W. by N.	2½	Variation 2¾ points West.
2		2	6			
3		3	2			
4	W. by S.	5		N.W. by N.	1¾	
5		4	6			
6		4	4			
7		5				
8	W.N.W.	5	3	N.	1¼	
9		5	3			A current set by compass E.S.E., 9 miles, from the time the departure was taken to the end of the day.
10		5	4			
11	N.	6	5	W.N.W.	½	
12		6	5			

[8]

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	S. ½ W.	4	5	S.E. by E.	1¾	A point, Cape Agulhus, (So. Africa) in lat. 34° 50′ S. long. 20° 1′ E., bearing by compass N. ½ W., distance 15 miles.
2		4	3			
3	E.N.E.	3	8	S.E.	2¾	
4		3	6			
5		3	6			
6	S.S.E.	6	2	E.	¼	
7		6	3			
8		6	5			
9	E.S.E.	4	2	N E.	1½	
10		4	3			
11		4	5			
12	S.E.	6	8	E.N.E.	¾	
1		6	6			Variation 2½ points West.
2		6	4			
3		6	2			
4	E.N.E.	3		N.	2¼	
5		3	2			
6	N.W. by N.	4	8	N.E. by N.	1	
7		5				
8	S.E. ½ E.	7	4	N.E. by E.	½	A current set by compass W. by S., 2½ miles an hour from the time the departure was taken to the end of the day.
9		7	4			
10		7				
11	N.E.	5	6	N.N.W.	¾	
12		6	5			

[9]

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	S.W.	5	3	W.N.W.	1	A point in lat. 0° 39′ S.,
2		5	4			long. 0° 57′ E., bearing by
3	W.N.W.	4	4	S.W.	1¼	compass N.E. by E. ½ E.,
4		4	3			distance 17 miles.
5	W. by S.	8	2	S. by W.	½	
6		8	3			
7		9	4		¼	
8		9	4			
9	S.E. by S.	5	6	S.W. by S.	¾	
10		5	4			
11		5				
12	S.W. by W.	4	4	S. by E.	1½	Variation 1¾ point West.
1		4	3			
2	E. by S.	4	2	Ditto.	1¼	
3		4	4			
4	S.S.W. ½ W.	3	6	S.E. ½ S.	2¼	
5		3	4			
6		4				
7	S.W.	4	5	S.S.E.	1½	
8		4	6			
9	S. by E.	3	2	S.W. by W.	1¾	A current set by compass
10		3	4			S.W. ½ W., 35 miles, from
11	S.W. ½ S.	3	2	W. by N. ½ N.	2	the time the departure was
12		3	5			taken to the end of the day.

[10]

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	E.	8	2	S.S.E.	¼	A point, Cape East, in lat.
2		7	8			37° 42′ S., long. 178° 40′ E.,
3		7	5			bearing by compass W. ¾ S.,
4		7	4			distance 13 miles.
5	S.	5	2	E.S.E.	¾	
6		5	3			
7	N.N.E.	4	8	E.	1¼	
8		4	6			
9		5				
10	S.E. ½ E.	4	2	N.E. by E. ½ E.	2	
11		4				
12		3	8			Variation 1¼ point East.
1	E.S.E.	5	2	N.E.	1	
2		5	4			
3		5	5			
4	E. by N. ½ N.	4	4	N. by E.	2¼	
5		4				
6	Ditto.	4	6	Ditto.	1¾	
7	E.	7	5	N.N.E.	¼	
8		7	4			
9		7	3			A current set by compass
10	E. ½ N.	6	7	S.E. by S.	½	E. by N. ½ N., 48 miles, from
11		6	5			the time the departure was
12		6	4			taken to the end of the day.

[11]

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	W.S.W.	6	5	S.	$\frac{3}{4}$	A point, Isle of Mas à Fuera, in lat. 33° 49′ S., long. 80° 54′ W., bearing by compass S.E. by E. $\frac{3}{4}$ E., distance 19 miles.
2		6	5			
3		6	4			
4	W.N.W.	7	4	S.W.	$\frac{1}{4}$	
5		7	6			
6		7	7			
7	S.S.W.	6	5	W.	$\frac{1}{2}$	
8		6	4			
9		6	5			
10		6	3			
11	S.W.	5	3	W.N.W.	1	
12		5	4			
1		5	2			Variation 15° East.
2	W.S.W.	4	5	N.W.	$1\frac{1}{4}$	
3		4	4			
4	S.W. by S.	6	3	W. by N.	$\frac{1}{2}$	
5		6	4			
6		6	2			
7	S. $\frac{3}{4}$ E.	3	2	S.W. by W.	$2\frac{1}{4}$	
8		2	8			
9	W. by N.	4	2	S.W. by S.	$1\frac{3}{4}$	A current set by compass S.W. $\frac{1}{4}$ W., 24 miles, from the time the departure was taken to the end of the day.
10		3	6			
11		3	6			
12	W. by S. $\frac{1}{2}$ S.	7	3	S. $\frac{1}{2}$ W.	$\frac{1}{2}$	

[12]

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	W.S.W.	4	5	S.	1	A point in lat. 25° 39′ S., long. 45° 7′ E., bearing by compass N.W. by W. $\frac{3}{4}$ W., distance 13 miles.
2		4	3			
3		3			$2\frac{1}{4}$	
4		2	8			
5	S.S.W.	2	6	S.E.	$2\frac{1}{2}$	
6		2	4			
7		2			$2\frac{3}{4}$	
8	S.	4		E.S.E.	$1\frac{1}{2}$	
9		4	2			
10	S.S.E.	5	5	E.	$\frac{3}{4}$	
11		5	4			
12		5	1			
1	N.N.E.	5		Ditto.	$1\frac{1}{4}$	
2		4	8			Variation 24° West.
3		3			$2\frac{1}{4}$	
4		2	3		3	
5	up N.E. by N.					
6	off N. by E.			E. by S.	6	
7						
8	up S. by E.					
9	off S. by W.			Ditto.	6	
10						
11	S. by E.	2		Ditto.	4	Allow $1\frac{1}{2}$ miles an hour for drift while hove-to.
12		2	3		$3\frac{1}{2}$	

PRELIMINARY RULES IN NAUTICAL ASTRONOMY.

CIVIL DAY AND ASTRONOMICAL DAY.

THE *civil day* begins at midnight, and ends the following midnight, the interval being divided into twice twelve hours: the first twelve hours, which are before noon, are denoted by A.M. *(ante meridiem)*; the latter are afternoon, and styled P.M. *(post meridiem.)*

The *astronomical day* begins at noon, and ends the following noon, and is later than the civil day by twelve hours. The hours are reckoned throughout, or continuously from 0^h to 24^h. The distinction of A.M. and P.M. is not recognised in astronomical time.

Given civil time at ship to reduce it to astronomical time.

RULE XXXIX.

1°. *If the civil time at ship be* P.M., *it will also be astronomical time,* P.M. *being omitted.*

2°. *If the civil time at ship be* A.M., *add twelve to the hours, and put the day one back.*

EXAMPLES.

Ex. 1. October 7th, at $3^h\ 20^m$ P.M., civil time, is October 7th, at $3^h\ 20^m$ astronomical time.

Ex. 2. October 7th, at $3^h\ 20^m$ A.M., civil date, is October $6^d\ 15^h\ 20^m$ astronomical date; since 7^d less 1^d is 6^d, and 12^h added to $3^h\ 20^m$ is $15^h\ 20^m$.

Ex. 3. January 31st, at $7^h\ 20^m$ P.M., civil time, is January 31st, at $7^h\ 20^m$ astronomical time.

Ex. 4. February 1st, at $6^h\ 18^m$ A.M., civil date, is January $31^d\ 18^h\ 18^m$ astronomical date; since February 1^d, diminished by 1^d, gives January 31^d, and 12^h added to $6^h\ 18^m$ is $18^h\ 18^m$.

Ex. 5. What is the astronomical date corresponding to 1866, January 1st, 8^h A.M.? The corresponding astronomical date is 1865, December $31^d\ 20^h$. In this case the year is diminished by 1, since in diminishing the day of the month by 1, the reckoning throws us back into the last month of the previous year, *i.e.*, the day before January 1st 1866, also 12^h added to 8^h is 20^h.

EXAMPLES FOR PRACTICE.

Express the following civil dates in astronomical time:—

1.	Jan. 2nd,	4^h	38^m	9^s	A.M.
2.	Feb. 27th,	8	12	0	P.M.
3.	Aug. 14th,	6	28	40	P.M.
4.	April 1st,	7	54	19	A.M.
5.	June 4th,	4	18	3	A.M.
6.	Sept. 1st,	8	10	52	A.M.
7.	Dec. 31st,	6^h	18^m	34^s	P.M.
8.	July 1st,	8	3	24	P.M.
9.	July 1st,	11	30	10	A.M.
10.	Oct. 1st,	0	10	12	P.M.
11.	1865, Jan. 1st,	8	9	50	A.M.
12.	1866, Jan. 1st,	0	44	12	A.M.

LONGITUDE IN ARC AND LONGITUDE IN TIME.

THE earth rotates uniformly on her axis once in twenty-four hours, and thus every spot on her surface describes a complete circle, or 360°, in that space of time: hence the longitude of any place is proportional to the time the earth takes to revolve through the angle between the first meridian and the meridian of the place, and thus the longitude of a place may be expressed either in *arc* or in *time*.* Longitude in arc and longitude in time are easily convertible, for since 360° is equivalent to 24^h ($360 \div 24 = 15°$), 15° is equivalent to 1^h, 1° to 4^m, and 1′ to 4^s; and the following rules are sufficiently clear.

TO CONVERT ARC (OR LONGITUDE) INTO TIME.

RULE XL.

Multiply the given longitude by 4, this turns the degrees (°) into minutes (^{m}) of time, minutes (′) into seconds (^{s}) of time, and the seconds (″) into thirds (^{t})† of time.

EXAMPLES.

Ex. 1. Convert 12° 18′ 15″ into time.

$$\begin{array}{r} 12°\ 18'\ 15'' \\ 4 \\ \hline 49^m\ 13^s\ 0^t \end{array}$$

Ex. 2. Convert 25° 15′ 16″ into time.

$$\begin{array}{r} 25°\ 15'\ 16'' \\ 4 \\ \hline 6{,}0)10{,}1\ \ 1\ \ 4 \\ \hline 1^h\ 41^m\ 1^s\ 4^t \end{array}$$

* In reckoning by arc, each degree is divided into sixty minutes, and each minute into sixty seconds. In reckoning by time, each hour is also divided into sixty minutes, and each minute into sixty seconds. But a distinct notation for each of these has been adopted, degrees, minutes, and seconds, being represented by ° ′ ″, and hours, minutes, and seconds, by $^{h\ m\ s}$; and care should be observed not to use the same marks for both, great confusion arising from so doing.

† A third is the name given to the sixtieth part of a second.

Ex. 3. Turn 77° 2′ 10″ into time.

$$\begin{array}{r} 77^\circ\ 2'\ 10'' \\ 4 \\ \hline 6{,}0)30{,}8\ \ 8\ \ 40 \\ \hline 5^h\ 8^m\ 8^s\ 40^t \end{array}$$

Ex. 4. What time corresponds to 127° 32′ 40′?

$$\begin{array}{r} 127^\circ\ 32'\ 40'' \\ 4 \\ \hline 6{,}0)51{,}0\ \ 10\ \ 40 \\ \hline 8^h\ 30^m\ 10^s\ 40^t \end{array}$$

Ex. 5. What time is equivalent to 15° 47′ 55′?

$$\begin{array}{r} 15^\circ\ 47'\ 55'' \\ 4 \\ \hline 6{,}0)6{,}3\ \ 11\ \ 40 \\ \hline 1^h\ 3^m\ 11^s\ 40^t \end{array}$$

Ex. 6. Convert 144° 36′ 45″ into time.

$$\begin{array}{r} 144^\circ\ 36'\ 45'' \\ 4 \\ \hline 6{,}0)57{,}8\ \ 27\ \ 0 \\ \hline 9^h\ 38^m\ 27^s\ 0^t \end{array}$$

Examples for Practice.

Reduce the following arcs into time:—

1.	18° 54′	7.	12° 40′ 45″	13.	137° 27′	19.	96° 10′ 45″
2.	67 42	8.	76 20 30	14.	1 25	20.	140 32 10
3.	0 58·6	9.	49 4 20	15.	0 26·8	21.	14 2 30
4.	9 14	10.	163 2 48	16.	0 37·4	22.	2 18 12
5.	108 37	11.	10 27 14	17.	2 29	23.	84 42 30
6.	0 13·5	12.	51 10 12	18.	156 52	24.	178 49 45

TO CONVERT TIME INTO LONGITUDE.

RULE XLI.

Reduce the hours and minutes into minutes, and divide all by 4, and the quotient will be the degrees, minutes, &c., of the corresponding longitude.

Examples.

Ex. 1. Turn $1^h\ 5^m\ 12^s$ into arc.

$$\begin{array}{r} 1^h\ 5^m\ 12^s \\ 60 \\ \hline 4)65\ \ 12\ \ 0 \\ \hline 16^\circ\ 18'\ 0'' \end{array}$$

Ex. 2. Reduce $6^h\ 24^m\ 43^s$ into arc.

$$\begin{array}{r} 6^h\ 24^m\ 43^s \\ 60 \\ \hline 4)384\ \ 43\ \ 0 \\ \hline 96^\circ\ 10'\ 45'' \end{array}$$

Ex. 3. What arc corresponds to $0^h\ 47^m\ 36^s$?

$$\begin{array}{r} 4)0^h\ 47^m\ 36^s \\ \hline 11^\circ\ 54' \end{array}$$

Ex. 4. What is the equivalent arc to $9^h\ 25^m\ 37^s$?

$$\begin{array}{r} 9^h\ 25^m\ 37^s \\ 60 \\ \hline 4)565\ \ 37\ \ 0 \\ \hline 141^\circ\ 24'\ 15'' \end{array}$$

Ex. 5. Convert $8^h\ 17^m\ 35^s{\cdot}5$* into arc.

$$\begin{array}{r} 8^h\ 17^m\ 35^s{\cdot}5 \\ 60 \\ \hline 4)497\ \ 35\ \ 30 \\ \hline 124^\circ\ 23'\ 52^s{\cdot}5 \end{array}$$

Ex. 6. Convert $11^h\ 39^m\ 50^s{\cdot}7$ into arc.

$$\begin{array}{r} 11^h\ 39^m\ 50^s{\cdot}7 \\ 60 \\ \hline 4)699\ \ 50\ \ 42 \\ \hline 174^\circ\ 57'\ 40''{\cdot}5 \end{array}$$

Examples for Practice.

Convert the following times into arc:—

1.	$1^h\ 13^m\ 52^s$	6.	$9^h\ 49^m\ 38^s$	11.	$0^h\ 21^m\ 30^s{\cdot}9$	16.	$0^h\ 20^m\ 41^s$
2.	3 52 4	7.	0 34 58·2	12.	11 41 6·66	17.	0 36 56
3.	0 42 12	8.	1 41 1·6	13.	0 3 52	18.	5 0 51
4.	11 15 21	9.	3 4 28	14.	0 9 56	19.	11 59 57
5.	2 7 19	10.	8 17 6	15.	0 0 52	20.	0 1 52

To find the Greenwich date, the time at any other place and the longitude being given.

RULE XLII.

1°. *Express the ship time astronomically* (Rule XXXIX, page 113).

2°. *Convert the longitude into time* (Rule XL, page 114).

3°. In West longitude.—ADD *longitude in time to ship time—the sum if* less *than* 24 *hours, is the corresponding Greenwich date on the same day with the ship date; if* greater *than* 24 *hours, reject the* 24 *hours, and put the day one forward.*

4°. In East longitude.—*From ship astronomical time* SUBTRACT *longitude in time, if* less *than the hours, minutes, &c., of ship date—the remainder is the corresponding Greenwich date in the* same day as the ship date; *if the longitude in time be* greater *than the hours, minutes, &c., of ship astronomical,* ADD 24 *hours to the latter, and put the day one back before the subtraction is made.*

5°. When it is noon at the place.—*The longitude in time, if* west, *is the Greenwich date (apparent time); but if* east, SUBTRACT *the longitude in time from* 24 *hours, the remainder is the Greenwich date (apparent time) after noon of the preceding day.*

Examples.

Ex. 1. November 9th, at $4^h\ 10^m$ P.M. apparent time at ship, longitude 32° 45′ W.; required the corresponding time at Greenwich, or the Greenwich date.

Ship date (A.T.) Nov.	$9^d\ 4^h\ 10^m$	Longitude	32° 45′
Long. in time	+ 2 11		4
Greenwich date	9 6 21		6,0)13,1 0
			$2^h\ 11^m\ 0^s$

* *Tenths* of seconds multiplied by six, give *thirds*.

Ex. 2. June 5th, at $7^h\ 15^m$ A.M., app. time at ship, long. 140° 30′ E.; find corresponding Greenwich date.

Ship date (A.T.) June	$4^d\ 19^h\ 15^m$
Longitude in time	— 9 22
Green. date (A.T.) June	4 9 53

Ex. 3. January 3rd, at $8^h\ 12^m$ P.M., mean time at ship, long. 50° 45′ E.: find Greenwich date.

Ship date (M.T.) January	$3^d\ 8^h\ 12^m$
Longitude in time	— 3 23
Green. date (M.T.) Jan.	3 4 49

Ex. 4. April 27th, at $5^h\ 35^m\ 45^s$ A.M., app. time at ship, long. 122° 13′ W.; what is corresponding Greenwich date?

Ship date (A.T.) April	$26^d\ 17^h\ 35^m\ 45^s$
Longitude 122° 13′ W.	+ 8 8 52
	26 25 44 37
	— 24
Green. date (A.T.) April	27 1 44 37

Ex. 5. July 20th, at $3^h\ 35^m\ 7^s$ P.M., mean time at ship, long. 85° 24′ E.; find corresponding Greenwich date.

Ship date (M.T.) July	$20^d\ 3^h\ 35^m\ 7^s$
	+ 24
or	19 27 35 7
Longitude 85° 24′ E.	— 5 41 36
Green. date (M.T.) July	19 21 53 31

In example 4, the added longitude changes the day of the month; and in example 5, also, a day (or 24 hours) is borrowed before the subtraction is made, since the longitude in time exceeds the astronomical ship date.

Ex. 6. 1866, January 1st, $3^h\ 40^m\ 20^s$ P.M., mean time at ship, long. 95° 7′ E.; find the Greenwich date.

Ship date (M.T.) 1866, Jan.	$1^d\ 3^h\ 40^m\ 20^s$
Longitude 95° 7′ E.	— 6 20 28
Green. date (MT) 1865, Dec.	31 21 19 52

Ex. 7. 1865, January 1st, $9^h\ 1^m$ A.M., mean time at ship, long. 107° 4′ W.; find the Greenwich date.

Ship date (M.T.) 1864, Dec.	$31^d\ 21^h\ 1^m\ 0^s$
Longitude 107° 4′ W.	+ 7 8 16
Green. date (M.T.) 1865, Jan.	1 4 9 16

Ex. 8. 1865, June 12th, $6^h\ 40^m$ A.M., app. time at ship, long. 42° 16′ W.; find the Greenwich date.

Ship date (A.T.) June	$11^d\ 18^h\ 40^m\ 0^s$
Longitude 42° 16′ W.	+ 2 49 4
Green. date (A.T.) June	11 21 29 4

Ex. 9. 1865, October 1st, long. 2° W., the sun on meridian; required Greenwich date (app. time).

Ship date (A.T.) October	$1^d\ 0^h\ 0^m$
Longitude 2° W.	+ 8
Green. date (A.T.) October	1 0 8

Ex. 10. Required the Greenwich date when the sun is on the meridian of a place in long. 80° 44′ E., on January 12th.

The sun being on the meridian, it is apparent noon; hence—

Ship date (A.T.) Jan.	$12^d\ 0^h\ 0^m\ 0^s$
Longitude 80° 44′ E.	— 5 22 56
Green. date (A.T.) Jan.	11 18 37 4

Ex. 11. What is the Greenwich date when the sun is on the meridian of a place in long. 155° 19′ W., on March 31st?

Ship date (A.T.) March	$31^d\ 0^h\ 0^m\ 0^s$
Long. 155° 19′ W.	+ 10 21 16
Green. date (A.T) March	31 10 21 16

In example 10, the hours, &c., of longitude to be subtracted are to be taken from a borrowed day, thus making the day of the month at Greenwich one less than at the place. See Rule XLII, 5°, page 116.

Ex. 12. 1865, February 1st, long. 135° E.; find the Greenwich date when the sun is on the meridian.

Ship date (A.T.) February	1^d	0^h	0^m
Longitude 135° E.	—	9	0
Green. date (A.T.) January	31	15	0

Ex. 13. 1866, January 1st, the ship in long. 160° 30′ E.; required the Greenwich date when the sun is on the meridian.

Ship date (A.T.) 1866, Jan.	1^d	0^h	0^m
Longitude 160° 30′ E.	—	10	42
Green. date (A.T) 1865, Dec.	31	13	18

Examples for Practice.

Required the Greenwich date in each of the following examples:—

1.	1865, January 6th,	at 3^h	40^m	16^s P.M.,	apparent time,	long.	66°	56′	0″	W.
2.	„ February 13th,	at 8	40	3 A.M.	apparent time,	long.	21	4	0	W.
3.	„ February 1st,	at 5	10	50 A.M.	mean time,	long.	145	20	30	E.
4.	„ March 15th,	at 9	16	22 P.M.	apparent time,	long.	17	4	0	E.
5.	„ April 11th,	at 1	40	0 A.M.	apparent time,	long.	47	28	45	E.
6.	„ May 15th,	at 8	38	35 A.M.	apparent time,	long.	141	51	15	W.
7.	„ June 1st,	at 6	14	10 A.M.	mean time,	long.	50	12	0	W.
8.	„ November 1st,	at 5	0	10 P.M.	mean time,	long.	114	30	0	E.
9.	„ December 1st,	at 8	0	5 A.M.	mean time,	long.	158	10	0	W.
10.	„ July 1st,	at 4	0	33 P.M.	apparent time,	long.	170	55	15	E.
11.	„ August,	at 6	31	32 P.M.	apparent time,	long.	100	17	30	E.
12.	„ September 1st	at 8	29	1 A.M.	mean time,	long.	148	47	30	W.
13.	„ December 28th,	at 2	42	10 P.M.	mean time,	long.	50	40	0	E.
14.	„ July 8th,	at 0	4	36 A.M.	apparent time,	long.	178	51	0	W.
15.	„ February 1st,	at Noon,			apparent time,	long.	153	40	0	E.
16.	„ June 1st,	at Noon,			apparent time,	long.	83	50	0	E.
17.	„ March 2nd,	at Noon,			apparent time,	long.	1	25	0	W.
18.	„ September 1st,	at Noon,			apparent time,	long.	8	20	0	E.
19.	„ November 1st,	at Noon,			apparent time,	long.	66	5	0	E.
20.	1866, January 1st,	at Noon,			apparent time,	long.	149	10	0	E.

REDUCTION OF ELEMENTS FROM NAUTICAL ALMANAC.

The *Nautical Almanac* contains the right ascension, declination, &c., of the principal heavenly bodies for certain fixed times at Greenwich; the right ascension and declination of the sun and planets, for example, being given for every day at noon ($0^h\ 0^m\ 0^s$), while for the moon these elements are given for every hour. At a place under any other meridian than that of Greenwich, or at any other time of the day than that for which any quantity is given, it is requisite to apply a correction to that taken from the *Almanac*, in order to reduce it to its value at the given

instant. For this purpose we may either apply the common rules of proportion, or, which is in general the simplest method, make use of certain tables computed for the purpose, called tables of *proportional* logarithms.

TO REDUCE SUN'S DECLINATION.

FIRST METHOD—By proportional logarithms.

RULE XLIII.

1° *Get a Greenwich date by means of ship time, expressed astronomically, and longitude* (see Rule XLII, page 116), *or by means of chronometer.*

2°. *Take out of the* Nautical Almanac *the declination for the noon at Greenwich, and that following it.*

(*a*) When Greenwich date is given in *apparent* time, use Page I of the month, but for *mean* time, use Page II of the month.

(*b*) The tenths of seconds (″) of declination may be rejected when less than five, but call them 1″ when they amount to five, or above—thus 42″·7 would be 43″.

3°. *When the declinations are of* like *names, take their difference; but when of* different *names, take the sum: this is the daily variation of declination.*

(a) *When the declination is* increasing, *place the sign of* addition (+) *before the daily variation; but when the declination is* decreasing, *place the sign of* subtraction (—) *before it.*

4°. *Under the daily variation place the hours and minutes of Greenwich time, and take from the table* (Table XXI A, Raper, or XXXIII, Norie) *log. of change of declination in 24 hours, and log. of hours and minutes of Greenwich time; the sum of these logs. found in the table will give the* proportional part *of daily change of declination.*

(*a*) When the seconds of time (in Greenwich date) are less than 30^s, they may be rejected; but if above 30^s, increase the minutes of time by 1^m; thus, Greenwich time $2^h\ 35^m\ 40^s$ would, in using the tables, be called $2^h\ 36^m$.

(*b*) In using Table XXI A, Raper, or Norie XXXIII, minutes (′) of declination, and hours of time (^{h}), are found at the top of the columns; seconds (″) of declination, and minutes (^{m}) of time, at the side columns.

5°. *Apply the proportional part to the declination at the first noon,* adding *when the declination is* increasing; *but* subtracting *when the declination is* decreasing; *the* result is the declination at the time required.

(a) *If the proportional part, when* subtracted, *exceed the declination itself,* subtract *the* declination *from the* proportional part; *the* remainder *is the* declination *of the* contrary name.

In March when the declination changes from South to North, and in September when it changes from North to South, if the correction, by being subtractive, exceeds the declination, subtract the declination from the correction, and call the remainder N. in March, but S. in September. See examples, 3 and 6.

SECOND METHOD—By the hourly difference.

RULE XLIV.

1°. *Find a Greenwich date, as before.*

2°. *Take out of* Nautical Almanac *the declination at noon of Greenwich date, and a little to the right place the "difference for* 1 *hour," found in page* 1, *N.A.**

3°. *Multiply this last quantity by the hours and fractional parts of an hour of Greenwich date; the product, reduced to minutes and seconds, is the change of declination in the time from noon.*

4°. *Apply this change to declination at noon,* adding *it when declination is* increasing, *but* subtracting *it when declination is* decreasing; the result is the declination sought.

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* In the Nautical Almanac for 1863 and following years, the quantities given in the column marked "Diff. for 1 hour," are not the 1-24th part of the daily variation as heretofore, but the *hourly change which the declinatian is undergoing at the time of sun's transit,* and is obtained by dividing the change of the declination (Page I) between the day before and the day after the given day by 48. In order, therefore, to the accurate determination of the declination at any given time (including, of course, the second difference), the "Diff. for 1 hour" must be reduced to a time midway between that for which the declination is given and that for which it is required, that is, for the middle time between noon of the given day, and the given time on that day.

Example.—Greenwich date, January $25^d\ 8^h$, the middle time between noon 25th and $25^d\ 8^h$ is $25^d\ 4^h$.

Having found middle time, take out of *Nautical Almanac* the hourly difference for noon of given day and hourly difference for next day, take the difference of them, which is daily change of hourly difference, and take proportionate parts of this change for middle time, which apply to hourly difference at noon of given day, adding when hourly difference is increasing, and subtracting when decreasing. By using the hourly difference as heretofore, a not inconsiderable error may arise (sometimes amounting to 12″). It is surprising that no explanation has been given in the Nautical Almanac as to the above new plan for hourly differences, which is a very ingenious method for finding the declination as correct as by using second differences; yet nautical men will not, it is presumed, trouble themselves by proportioning for *hourly differences.* The better plan would be to proceed according to the preceding rule (Rule XLIII), using Norie's Table XXXIII, or Raper's XXI A; and it is to be hoped that this method will be adopted at the examinations by the Marine Boards. The same remarks apply to the equation of time and to the sun's right ascension.

EXAMPLES.

Ex. 1. 1865, January 13th, at $3^h\ 54^m\ 16^s$ P.M., app. time at ship, long. 30° 4′ E.; find the sun's declination.

Ship date (A.T.) January	13^d	$3^h 54^m 16^s$
Longitude 30° 4′ E.	—	2 0 16
Green. date (A.T.) January	13	1 54 0

Longitude	30°	4′
		4
	6,0)12,0	16
	2 0	16

Decl. app. noon, page I, N.A.

13th,	21° 25′ 28″ S.	
14th,	21 14 53 S.	
Daily var.	10 35	log. 3556
Green. time	$1^h 54^m$	log. 1·1015
Correction	— 50	log. 1·4571
	21 25 28 S.	
Red. decl.	21 24 38 S.	

The correction 50″, is subtracted from declination at noon, because the declination is decreasing.

The middle time between 13 days at noon, and $13^d\ 1^h\ 54^m$ is $13^d\ 1^h$ nearly.

H. diff. 13th, noon	25″·94
14th, noon	26 ·97
Change in 24^h	+ 1·03
Change in 1^h	+ ·04
H. diff. 13th, noon	25·94
H. diff. at 1^h	25·98
$1^h\ 54^m$ =	1·9
	23382
	2598
Correction	49·362 or 49″
Decl. 13th, noon	21° 25′ 28″ S.
Correction	— 49
Reduced decl.	21 24 39

Ex. 2. 1865, May 21st, at $7^h\ 50^m$ A.M., mean time at ship, long. 149° 30′ E.; required the sun's declination.

Ship date (M.T.) May	$20^d\ 19^h 50^m$
Longitude 149° 30′ E.	— 9 58
Green. date (M.T.) May	20 9 52

Decl., page II., NA.

20th,	20° 2′ 28″ N.	
21st,	20 14 44 N.	
Daily var.	12 16	log. 2915
Green. time	$9^h 52^m$	log. 3860
Correction	+ 5 3	log. 6775
20th, noon	20 2 26 N.	
Red. decl.	20 7 29 N.	

The correction 5′ 3″ is *added* to the declination at noon, because the declination is *increasing*.

Ex. 3. 1865, March 21st, $3^h\ 10^m\ 12^s$ P.M., app. time at ship, long. 175° 48′ E.; required the sun's declination.

Ship date (A.T.) Mar.	$21^d\ 3^h 10^m 12^s$
or	20 27 10 12
Longitude 175° 48′ E.	— 11 43 12
Green. date (AT) Mar.	20 15 27

20th,	0° 1′ 56·3″ S.	
21st,	0 21 44·8 N.	
Daily var.	23 41 N.	log. 0058
Green. time	$15^h 27^m$	log. 1913
Correction	15 15 N.	log. 1971
20th, noon	0 1 56 S.	
Red. decl.	0 13 19 N.	

The S. decl. is decreasing, and must decrease to 0 before N. decl. commences; the correction being *subtractive* (on account of the first decl. decreasing) and *greater* than the decl., the decl. is subtracted from the correction and the remainder, which is named N., is the red. decl.

Ex. 4. 1865, Feb. 11th, $8^h\ 54^m\ 47^s$ P.M., app. time at ship, long. $11°\ 4'$ W.; required the sun's declination.

Ship date (A.T.) Feb.	11^d	$8^h 54^m 47^s$	
Longitude $11°\ 4'$ W.	+	44 16	
Green. date (A.T) Feb.	11	9 39 3	

Decl., page I, N.A.

11th,	$13°\ 54'\ 27''$ S.	
12th,	13 34 31 S.	
Daily var.	19 56	log. 0806
Green. time	$9^h 39^m$	log. 3957
Correction	— 8 1	log. 4763
11th, noon	13 54 27 S.	
Red. decl.	13 46 26 S.	

Ex. 5. 1865, July 31st, $8^h\ 45^m\ 30^s$ A.M., mean time at ship, long. $65°\ 7'$ W.; required sun's declination.

Ship date (M.T.) July	30^d	$20^h 45^m 30^s$	
Longitude $65°\ 7'$ W.	+	4 20 28	
Green. date (M.T) July	31	1 5 58	

Decl., page II, N.A.

31st,	$18°\ 13'\ 18''$ N.	
32nd,	17 58 16 N.	
Daily var.	15 2	
Green. time	$1^h\ 6^m$	
Correction	— 0 41	log. ·2031
31st, noon	18 13 18 N.	log. 1·3388
Red. decl.	18 12 37 N.	log. 1·5419

Ex. 6. 1865, Sept. 23rd, at app. noon, long. $108°\ 45'$ E.; required the sun's declination.

Green. date (A.T.) Sept. $22^d\ 16^h 45^m$

Decl., page I, N.A.

22nd,	$0°\ 12'\ 47''$ N.	
23rd,	0 10 37 S.	
Daily var.	23 24 S.	log. 0110
Green. time	$16^h 45^m$	log. 1562
Correction	16 20 S.	log. 1672
22nd, noon	0 12 47 N.	
Red. decl.	0 3 33 S.	

Ex. 7. 1865, September 10th, the sun on the meridian, long. $100°\ 35'$ E.; required the sun's declination.

Ship date (A.T.) Sept.	10^d	$0^h\ 0^m\ 0^s$	
Longitude $100°\ 35'$ E.	—	6 42 20	
Green. date (A.T.) Sept.	9	17 17 40	

Decl., page I, N.A.

9th,	$5°\ 13'\ 27''$ N.	
10th,	4 50 42 N.	
Daily var.	22 45	log. 0232
Green. time	$17^h 18^m$	log. 1422
Correction	— 16 24	log. 1654
9th, noon	5 13 27 N.	
Red. decl.	4 57 3 N.	

Degree of dependence.—The sun's declination changes nearly 1′ an hour, or 1″ in 1^m, in March and September; hence to ensure it to 1″ in the extreme case, the Greenwich date must be true to 1^m.

Examples for Practice.

In each of the following examples it is required to find the sun's declination when the sun is on the meridian (at apparent noon):—

1. 1865, Jan. 19th, long. $86°\ 57'$ W.
2. „ Feb. 16th, long. 72 59 E.
3. „ April 2nd, long. 50 56 W.
4. „ Mar. 21st, long. 168 3 E.
5. „ May 8th, long. 10 35 W.
6. „ June 1st, long. 83 50 E.
7. „ June 21st, long. 167 15 E.
8. „ Mar. 20th, long. 129 0 W.
9. 1865, July 28th, long. $2°\ 0'$ W.
10. „ Aug. 19th, long. 82 30 W.
11. „ Sept. 22nd, long. 156 0 W.
12. „ Oct. 1st, long. 170 58 E.
13. „ Nov. 30th, long. 12 54 W.
14. „ Dec. 22nd, long. 179 52 E.
15. 1866, Jan. 1st, long. 156 48 E.
16. „ Sept. 23rd, long. 174 15 E.

Required the sun's declination in each of the following examples :—

17.	1865,	January 5th,	$6^h 23^m 32^s$ A.M.	app. time at ship	long. 108° 7′ W.
18.	„	February 2nd,	3 9 0 P.M.	app. time at ship	long. 52 45 W.
19.	„	March 31st,	6 2 12 P.M.	app. time at ship	long. 156 3 E.
20.	„	March 26th,	7 8 22 A.M.	mean time at ship	long. 72 47 E.
21.	„	April 15th,	7 28 0 A.M.	app. time at ship	long. 85 30 E.
22.	„	May 16th,	9 17 20 A.M.	mean time at ship	long. 45 40 W.
23.	„	April 29th,	2 26 52 P.M.	mean time at ship	long. 110 57 W.
24.	„	May 15th,	5 8 19 A.M.	app. time at ship	long. 17 58 W.
25.	„	June 10th,	8 45 0 P.M.	app. time at ship	long. 129 30 E.
26.	„	November 1st,	10 20 16 A.M.	mean time at ship	long. 11 17 E.
27.	„	September 1st,	8 20 40 A.M.	app. time at ship	long. 172 9 E.
28.	„	October 1st,	6 11 50 A.M.	mean time at ship	long. 68 15 W.
29.	„	December 16th,	4 35 32 A.M.	app. time at ship	long. 4 8 E.
30.	„	November 14th,	6 45 8 P.M.	mean time at ship	long. 100 2 E.

THE POLAR DISTANCE of a heavenly body is its angular distance from the elevated pole of the heavens; it is measured by the intercepted arc of the hour-circle passing through it, or by the corresponding angle at the centre of the sphere. According as the North or South pole is elevated, we have the *North Polar Distance* or the *South Polar Distance.*

To find the polar distance of a celestial object, proceed according to the following rule :—

RULE XLV.

When the latitude *of the place, and* declination *of the object, are of the* same *name,* subtract the declination *from* 90°; *but when the* latitude *and* declination *are of* contrary *names,* add the declination *to* 90°; the result in either case is the polar distance.

When the latitude is 0, the declination, either *added* to or *taken* from 90°, is the polar distance.

EXAMPLES.

LAT.	DECLINATION.	POLAR DISTANCE.
N.	8° 12′ 18″ S.	98° 12′ 18″
N.	22 30 0 N.	67 30 0
S.	2 31 15 S.	87 28 45
N.	30 23 15 S.	120 23 15
S.	7 22 32 N.	97 22 32
S.	26 43 12 S.	63 16 48
0	12 48 2 N.	102 48 2 or 77 11 58

TO FIND THE EQUATION OF TIME.

DAY APPARENT SOLAR, is the interval between two successive transits of the actual sun's centre over the same meridian; it begins when that

point is on the meridian. The apparent solar day is variable in length from two causes; first, the sun does not move uniformly in the ecliptic —its apparent path sometimes describing an arc of 57′, and at other times an arc of 61′ in a day; second, the ecliptic twice crosses the equinoctial—the great circle whose plane is perpendicular to the axis of rotation—and hence is inclined to it in its different parts; at the points of intersection the inclination is about 23° 27′, at two other limiting points they are parallel. A uniform measure of time is obtained by the invention of the *Mean Solar Day*.

Mean Solar Day is the interval between two successive transits of the *mean sun* over the same meridian; it begins when the mean sun is on the meridian. This fictitious body is conceived to move in the equinoctial with the mean motion of the actual sun in the ecliptic. The length of the mean solar day is the average length of the *apparent solar days* for the space of a solar year.

Equation of Time is the difference between apparent and mean time. It is measured by the angle at the pole of the heavens between two circles passing, the one through the apparent sun's centre, the other through the mean sun. The equation of time is so called because it enables us to reduce apparent to mean, or mean to apparent time. In consequence of the motion of the sun in the ecliptic being variable, and the ecliptic not being perpendicular to the axis of the earth's rotation, apparent time is variable, and this fluctuation is considerable, amounting to upwards of half an hour—apparent noon sometimes taking place as much as $16\frac{1}{4}^m$ before mean noon, and at others as much as $14\frac{1}{2}^m$ after. These are the greatest values of the equation of time; it vanishes altogether four times a year—this occuring about April 15th, June 15th, September 1st, and December 24th. It is calculated and inserted in the Nautical Almanac for every day in the year. On page I of each month the equation of time given is that to be used in deducing mean from apparent time; that on page II is to be used in deducing apparent from mean time. The difference in the value of the two arises from the one being that at apparent noon, and the other that at mean noon. As these may be separated by an interval of more than a quarter of an hour, the equation of time given in pages I and II may differ by a quarter of the "Diff. for 1 hour" given in the adjoining column. The equation of time is itself a portion of mean time.

FIRST METHOD.—By hourly differences.

RULE XLVI.

1°. *Get a Greenwich date.*

2°. *Take out of* Nautical Almanac, *page II of the month, the equation of time for the noon of Greenwich date, and mark it* additive *or* subtractive, *according to the heading of equation of time in page I of the month; also take from the column in page I, the "Diff. for 1 hour."**

3°. *Multiply the "Diff for 1 hour" by the hours, and, when great precision is necessary, by the fractional parts of an hour also. The result is the correction to be applied to the equation of time taken from the* Nautical Almanac, *and is to be* added *when equation of time is* increasing, *but* subtracted *when equation of time is* decreasing. *When the correction, being subtractive,* exceeds *the equation of time itself,* subtract *the equation of time from the correction; the remainder is the reduced equation of time sought—and it is to be* subtracted *from apparent time when equation of time at noon is directed to be* added, *but* added *to apparent time when equation of time at noon is directed to be* subtracted.

RULE XLVII.

1°. *Get a Greenwich date, as before.*

2°. *Take out of* Nautical Almanac, *page II, the equation of time for noon of Greenwich date, and the noon following it, prefixing* additive *or* subtractive *to them, according to the heading of equation of time, page I,* Nautical Almanac.

3°. *When both equations are marked* add, *or both* subtract, *their difference is the daily variation; but when one is marked* add, *and the other* subtract, *take the sum for the daily variation.*

4°. *Add together the log. of Greenwich time and log. of daily variation; the sum is log. of proportional part of daily variation, which find in the table.*

5°. *When first equation of time is* increasing, add *proportional part* to it; *but when equation of time is* decreasing, subtract from it the proportional part. *If proportional part, when* subtractive, exceeds *the equation of time itself,* take equation of time *from* it, *and the result is the equation of time sought—and is* additive *or* subtractive, *according to the directions for the second equation of time.*

---

* The Greenwich middle time being found, the hourly difference is reduced to it in the same way as directed for the declination (see Note, page 120).

Examples.

Ex. 1. 1865, January 29th, $6^h\ 53^m\ 49^s$ mean time at Greenwich; find equation of time to be applied to apparent time.

Eq. time, page 2, N.A.		
29th, *add*	$13^m 29{\cdot}0^s$	
30th, *add*	13 38·8	
Daily var.	9·8	
9·8 as 9′ 48″		log. 3890
	$6^h\ 54^m$	log. 5414
	2′ 49″	log. 9304
Or 2′ 49″ =	2·8	
29th, noon, *add*	13 29·0	
Red. eq. time	13 31·8	

(To be *added* to app. time.)

The mid. time between noon 29th, and $29^d\ 7^h$, or $29^d{\cdot}3$, is $29^d{\cdot}15$.

H. diff. 29th,	0·425
30th,	0·390
	·035
Mid. time	× ·15
	− ·00525
29th, noon,	0·425
H. diff. at Mid. time	0·420
Green. time	$\times\ 7^h$
Correction	2·940
or	+ 2·9
29th, noon,	13 29·0
Red. eq. time	13 31·9

(To be *added* to app. time.)

In the preceding example, the *tenths* of seconds (·8) in daily variation are multiplied by 6, in order to get *thirds*. The table is then entered with the seconds (9) at the top of the column, and the thirds (48) at the side for the log. The sum of the two logs. gives seconds and thirds; the *thirds* (49) are to be divided by 6, to reduce them to *tenths:* hence we obtain the proportional part of daily variation $2^s{\cdot}8$.

Ex. 2. 1865, March 27th, $23^h\ 26^m$ mean time at Greenwich; find equation time.

Eq. time, page II, N.A.		
27th, noon, *add*		$5^m 25{\cdot}5^s$
28th, noon, *add*		5 7·1
Daily variation		18·4
18·4 as 18′ 24″	log.	1154
$23^h\ 26^m$	log.	0104
17′ 58″	log.	1258
	or	18·0
27th, noon,		5 25·5
Red. eq. time		5 7·5

(To be *added* to app. time.)

Ex. 3. 1865, April 14th, $22^h\ 42^m$ mean time at Greenwich; required the equation of time.

Eq. time, page II, N.A.		
14th, noon, *add*		$0^m 13{\cdot}5^s$
15th, noon, *sub.*		0 1·6
		15·1
15·1 as 15′ 6″	log.	2012
$22^h\ 42^m$	log.	0242
14 17	log.	2254
14 17 =		14·3
15th, noon, *add*		0 13·5
Red. eq. time		0 0·8

(To be *sub.* from app. time.)

Ex. 4. 1865, December 24th, $8^h\ 54^m$ mean time at Greenwich; find the equation of time.

Eq. time 24th, *sub.*		$0^m\ 1{\cdot}8^s$
25th, *add*		$0\ \ 28{\cdot}1$
Daily variation		$2)29{\cdot}9$
		$14{\cdot}9$
$14{\cdot}9$ as $14'\ 54''$	log.	2070
$8^h 54^m$	log.	4308
$5'\ 32''$	log.	6378
2		
$11\ \ 4$	$=$	$11{\cdot}1$
24th, noon, *sub.*		$0\ \ 1{\cdot}8$
Red. eq. time		$0\ \ 9{\cdot}3$

(To be *added* to app. time.)

The daily variation is divided by 2, as it exceeds the limits of the tables, and the prop. part found is multiplied by 2.

Ex. 5. 1865, August 12th, $15^h\ 24^m$ mean time at Greenwich; find equation of time.

Eq. time, page II, N.A.		
12th, noon, *add*		$4^m 45{\cdot}7^s$
13th, noon, *add*		$4\ 35{\cdot}3$
		$10{\cdot}4$
$10{\cdot}4$ as $10'\ 24''$	log.	3632
$15^h 24^m$	log.	1927
$6'\ 41''$	log.	5559
$6'\ 41''$	$=$	$6{\cdot}7$
12th, noon,		$4\ 45{\cdot}7$
Red. eq. time		$4\ 39{\cdot}0$

(To be *added* to app. time.)

Examples for Practice.

In each of the following examples it is required to find the equation of time corresponding to the given Greenwich date:—

1.	1865,	Jan. 5th,	at	$12^h 33^m 0^s$ M.T.
2.	„	Feb. 18th,	at	13 20 0 M.T.
3.	„	Mar. 24th,	at	1 4 8 A.T.
4.	„	April 14th,	at	14 8 10 A.T.
5.	„	May 19th,	at	6 56 0 M.T.
6.	„	June 14th,	at	5 49 50 M.T.
7.	„	June 25th,	at	20 32 0 M.T.
8.	„	July 16th,	at	1 14 0 A.T.
9.	„	Aug. 31st,	at	21 14 40 A.T.
10.	„	Sept. 8th,	at	0 53 10 M.T.
11.	„	Oct. 5th,	at	19 19 2 A.T.
12.	„	April 14th,	at	16 21 55 A.T.
13.	1865,	June 14th,	at	$22^h 52^m 0^s$ M.T.
14.	„	Aug. 31st,	at	15 54 0 A.T.
15.	„	May 14th,	at	9 36 0 A.T.
16.	„	April 14th,	at	21 36 50 M.T.
17.	„	Nov. 14th,	at	21 35 0 A.T.
18.	„	July 20th,	at	20 57 16 M.T.
19.	„	Dec. 24th,	at	18 2 54 M.T.
20.	„	Oct. 26th,	at	7 56 21 M.T.
21.	„	Nov. 2nd,	at	13 42 34 A.T.
22.	„	Dec. 24th,	at	1 30 0 A.T.
23.	„	Aug. 31st,	at	10 35 0 M.T.
24.	„	Dec. 31st,	at	9 24 47 M.T.

CORRECTION OF THE OBSERVED ALTITUDE.

The corrections necessary to reduce an altitude observed from the sea-horizon with a quadrant or sextant, &c., to the *true* altitude, consist of the index correction, the dip, the correction of altitude, or the joint effect of refraction and parallax, and, in certain cases, of the semi-diameter.

The altitudes of heavenly bodies are observed from the deck of a ship at sea, with the sextant, for the purpose of finding latitude, longitude, &c. Such an altitude is called the "*observed altitude.*" There are certain instrumental and circumstantial sources of error by which this is affected :—(*a*) The sextant (supposed otherwise to be in adjustment) may have an index error: (*b*) The eye of the observer being elevated above the surface of the sea, the horizon will appear to be depressed, and the consequent altitude in reality too great: and (*c*) One of the limbs of the body may be observed instead of its centre. When the correction for these errors and method of observing are applied—"the index correction," "correction for dip," and "semi-diameter,"—the observed is reduced to the *apparent altitude.* But, again, for the sake of comparison and computation, all observations must be transformed into what they would have been, had the bodies been viewed through a uniform medium, and from one common centre—the centre of the earth. The altitude supposed to be so taken is called the "*true altitude;*" it may be deduced from the apparent altitude by applying the corrections called "corrections for refraction" (Table V, Norie, or XXXI, Raper), and "correction for parallax" (Table VI, Norie, or XXXIV, Raper), which, however, are sometimes given in tables combined under the names "correction in altitude" (Table XVIII, Norie). (*a′*) "Correction for refraction;" when a body is viewed through the atmosphere, refraction will cause the apparent to be greater than the true altitude; hence the correction for refraction is subtractive in finding the true from the apparent altitude. (*b′*) "Correction for parallax;" the position of the observer on the surface, especially for near bodies, will cause the apparent to be less than the true altitude; hence the correction for parallax is additive in finding the true from the apparent altitude.

TO CORRECT THE SUN'S ALTITUDE.

RULE XLVIII.

1°. *Correct the observed altitude of the sun for index error, if any.*

2°. Subtract *the dip answering to height of eye* (Table V, Norie, and Table XXX, Raper); *the remainder is the apparent altitude of the limb observed.*

3°. Subtract *the refraction* (Table IV, Norie, and XXXI Raper), add *the parallax* (Table VI, Norie, XXXIV, Raper); *or, take out the "correction in altitude of sun"* (Table XVIII, Norie), *and subtract it; the remainder is the* true *altitude of the observed limb.*

4°. *Take from* Page II *of the month in the* Nautical Almanac *the* sun's *semi-diameter,* adding *it when the sun's* lower limb (L.L.) *is observed, but* subtracting *it when the sun's* upper limb (U.L.) *is observed;* the result thus obtained is the true altitude of the sun's centre.

Examples.

Ex. 1. 1865, January 6th, the observed altitude sun's L.L. 39° 8′ 30″, index correction + 33″, height of eye 19 feet; required the true altitude.

Raper.

Obs. alt. sun's L.L.	39° 8′ 30″
Index correction	+ 33
	39 9 3
Dip (Table 30.)	− 4 15
App. alt. sun's L.L.	39 4 48
Ref. (Table 31.) } — Par. (Table 34.) }	− 1 5
True alt. sun's L.L.	39 3 43
Semi-diameter	+ 16 18
True altitude	39 20 1

Norie.

Obs. alt. sun's L.L.	39° 8′ 30″
Index correction	+ 33
	39 9 3
Dip (Table 5.)	− 4 11
App. alt. sun's L.L.	39 4 52
Corr. alt. (Table 18.)	− 1 3
True alt. sun's L.L.	39 3 49
Semi-diameter	+ 16 18
True altitude	39 20 7

Ex. 2. 1865, June 18th, the observed altitude sun's L.L. 71° 19′ 20″, index correction + 3′ 46″, height of eye 18 feet; required the true altitude.

Obs. alt. sun's L.L.	71° 19′ 20″
Index correction	+ 3 46
	71 23 6
Dip (Table 30.)	− 4 10
	71 18 56
Ref. − 0′ 20″ } Par. + 3 }	− 17
	71 18 39
Semid., p. II., N.A.	+ 15 46
True altitude	71 34 25

Obs. alt. sun's L.L.	71° 19′ 20″
Index correction	+ 3 46
	71 23 6
Dip (Table 5.)	− 4 4
	71 19 2
Corr. of alt. (Table 18.)	− 17
	71 18 45
Semi-diameter	+ 15 46
True altitude	71 34 31

Ex. 3. 1865, October 8th, the observed altitude sun's L.L. 19° 50′ 10″, index correction + 50″, height of eye 16 feet.

Obs. alt. sun's L.L.	19° 50′ 10″
Index correction	+ 50
	19 51 0
Dip	− 4 0
	19 47 0
Ref. − 2′ 41″ } Par. + 8 }	− 2 33
	19 44 27
Semi-diameter	+ 16 3
True altitude	20 0 30

Obs. alt. sun's L.L.	19° 50′ 10″
Index correction	+ 50
	19 51 0
Dip	− 3 50
	19 47 10
Correction altitude	− 2 29
	19 44 41
Semi-diameter	+ 16 3
True altitude	20 0 44

Ex. 4. 1865, August 8th, observed altitude sun's U.L. 12° 52′ 30″, index correction + 3′ 10″, height of eye 17 feet.

Obs. alt. sun's U.L.	12° 52′ 30″
Index correction	+ 3 10
	12 55 40
Dip 17 feet	− 4 5
	12 51 35
Ref. — 4′ 11″, Par. + 8	− 4 3
	12 47 32
Semi-diameter	− 15 49
True altitude	12 31 43

Obs. alt. sun's U.L.	12° 52′ 30″
Index correction	+ 3 10
	12 55 40
Dip	− 3 57
	12 51 43
Correction altitude	− 3 56
	12 47 47
Semi-diameter	− 15 49
True altitude	12 31 58

Examples for Practice.

1.	1865,	Jan. 29th,	Obs. alt. sun's L.L.	17° 44′ 30″	Index corr.	− 1′ 25″	Eye	16	feet.
2.	„	Feb. 18th,	„	48 4 10	„	+ 0′ 55″	„	12	„
3.	„	Mar. 24th,	„	29 50 30	„	+ 1 3	„	17	„
4.	„	April 20th,	„	76 3 0	„	− 1 27	„	10	„
5.	„	May 8th,	„	58 38 20	„	− 1 10	„	18	„
6.	„	June 19th,	„	28 48 30	„	− 1 14	„	20	„
7.	„	July 16th,	„	65 1 0	„	+ 0 17	„	14	„
8.	„	Aug. 7th,	„	85 13 20	„	− 2 10	„	18	„
9.	„	Sept. 2nd,	„	28 16 20	„	− 4 8	„	10	„
10.	„	Oct. 11th,	„	67 44 0	„	− 1 38	„	15	„
11.	„	Nov. 15th,	„	14 3 40	„	+ 4 1	„	12	„
12.	„	Dec. 14th,	„	U.L. 12 10 5	„	− 0 49	„	12	„
13.	„	Feb. 11th,	„	L.L. 69 32 10	„	+ 1 50	„	22	„
14.	„	Oct. 6th,	„	U.L. 9 10 30	„	+ 0 20	„	18	„
15.	„	Feb. 9th,	„	U.L. 20 18 15	„	+ 1 40	„	14	„

TO FIND THE LATITUDE BY A MERIDIAN ALTITUDE OF THE SUN.

RULE XLIX.

1°. *With the ship's date and longitude in time, find the Greenwich date* in apparent time (Rule XLII, 5°, page 116.)

2°. *Take the sun's declination from* Nautical Almanac *(page I of the month), and correct it for the Greenwich date* (Rule XLIII, page 119.)

3°. *Correct the observed altitude for index error, dip, semi-diameter, and refraction and parallax, and thus get the true altitude* (Rule XLVIII, page 128); *subtract true altitude from 90°: the result will be the true zenith distance.**

* When *true* altitude exceeds 90°, subtract 90° from it.

4°. *Call the zenith distance* N., *when the observer is North of sun, or when the sun bears South, call zenith distance* S., *when the observer is South of sun, or when it bears North.*

5°. Add *together the declination and zenith distance, when they have the* same *names* (see examples 1 and 3); *but take the* difference, *if their names be* unlike (see examples 2, 5, and 6); *the latitude is* N. *or* S., *as the greater is.*

6°. *When the declination is* 0°, *the zenith distance is the latitude, and of the* same *name as the* zenith distance (see example 7); and *when the zenith distance is* 0°, *the declination is the latitude, and of the* same *name as the* declination.

Examples.

Ex. 1. 1865, January 15th, in longitude 72° 42′ W., the observed meridian altitude of the sun's L.L. (lower limb) was 59° 42′ 10″, bearing north; index error + 2′ 10″, height of eye 14 feet: required the latitude.

The observation was made when the sun was on the meridian, that is, at apparent noon: the date, therefore, at the place of observation is January 15th, $0^h\ 0^m\ 0^s$. But the meridian of the place of observation is 72° 42′ W. of meridian of Greenwich, and therefore, the sun is 72° 42′ W. of meridian of Greenwich; or, in time $4^h\ 50^m\ 48^s$, since 72° 42′ is equivalent to $4^h\ 50^m\ 48^s$. It is, therefore, $4^h\ 50^m\ 48^s$ *past* apparent noon at Greenwich, and the Greenwich date is found by *adding* $4^h\ 50^m\ 48^s$ to the time of apparent noon, January 15th, thus:—

Ship date, January	15^d	0^h	0^m	0^s
Longitude 72° 42′ W. +		4	50	48
Greenwich date, Jan.	15	4	50	48

With this date the sun's declination must be taken out of *Nautical Almanac*, where it will be found in page I, for January. It may be reduced to Greenwich date by means of the tables, or by "Hourly diff.," thus—

Decl. app. noon.			
15th,	21° 3′ 54″ S.		
16th,	20 52 30 S.		
Daily var.	— 11 24	log.	3233
Green. time	$4^h 51^m$	log.	6945
	— 2 18	log.	1·0178
	21 3 54 S.		
Red. decl.	21 1 36 S.		

The mid. time is $15^d\ 2\frac{1}{2}^h$.	
H. diff. 15th,	$27^s{\cdot}98$
16th,	28·98
	10)1·00
$2\frac{1}{2}^h = \frac{1}{10}$ of a day	·10
	27·98
H. diff. at mid. time	28·08
$4^h\ 51^m =$	× 4·85
	6,0)136·1880
Correction	2 16
15th, noon,	21 3 54 S.
Red. decl.	21 1 38 S.

Raper.		*Norie.*	
Obs. alt. sun's L.L.	59° 42′ 10″N.	Obs. alt. sun's L.L.	59° 42′ 10″N.
Index error	+ 2 10	Index error	+ 2 10
	59 44 20		59 44 20
Dip (Table 30.)	— 3 40	Dip (Table 5.)	— 3 36
App. alt. sun's L.L.	59 40 40		59 40 44
Refraction (Table 31.)	— 34	Corr. alt. (Table 18.)	— 29
	59 40 6		59 40 15
Parallax (Table 34.)	+ 4	Semi-diameter	+ 16 18
True alt. sun's L.L.	59 40 10	True altitude	59 56 33
Semi-diameter	+ 16 18		90 0 0
True altitude	59 56 28	Zenith distance	30 3 27 S.
	90 0 0	Declination	21 1 36 S.
Zenith distance	30 3 32 S.	Latitude	51 5 3 S.
Declination	21 1 36 S.		
Latitude	51 5 8 S.		

Ex. 2. 1865, February 3rd, in longitude 139° 42′ W., the observed meridian altitude of the sun's L.L. 56° 56′ 56″, bearing south; index correction — 3′ 4″; height of eye 14 feet.

Ship date, February	$3^d\ 0^h\ 0^m\ 0^s$		Obs. alt. sun's L.L.	56° 56′ 56″S.
Long. 139° 42′ W.	+ 9 18 48		Index correction	— 3 4
Greenwich date	3 9 18 48			56 53 52
			Dip (Table 5, Norie)	— 3 36
Decl. app. noon.			App. alt. sun's L.L.	56 50 16
3rd,	16° 25′ 3″ S.		Corr. alt. (Table 18.)	— 0 32
4th,	16 7 9 S.		True alt. sun's L.L.	56 49 44
Daily var.	17 54	log. 1274	Semi-diameter	+ 16 15
Green. time	$9^h\ 19^m$	log. 4109	True altitude	57 5 59
	6 57	log. 5383		90 0 0
	16 25 3 S.		Zenith distance	32 54 1 N.
Red. decl.	16 18 6 S.		Declination	16 18 6 S.
			Latitude	16 35 55 N.

Using Raper's tables, the corrections are as follow: Index correction, — 3′ 4″; Dip, — 3′ 40″; Refraction, — 0′ 38″; Parallax, + 5″; Semi-diameter, + 16′ 15″; whence True Altitude is 57° 5′ 54″, and the Latitude 16° 36′ 0″ N.

Ex. 3. 1865, March 21st, longitude 109° 42′ E., observed meridian altitude of the sun's L.L. 52° 52′ 50″, bearing south; index correction, + 1′ 5″; height of eye 12 feet.

Greenwich date 20d 16h 41m 12s.
Decl. 20th, 0° 1′ 56″ S.
21st, 0 21 45 N.

Daily var.	23 41	log. 0058
Green. time	16h 41m	log. 1579
	16 28 N.	log. 1637
	0 1 56 S.	
Red. decl.	0 14 32 N.	

By Raper: dip, — 3′ 20″; ref., 0′ 44″; par., + 5″; semid., + 16′ 5″. True alt. 53° 6′ 1″ and Latitude 37° 8′ 31″ N.

Obs. alt. sun's L.L.	52° 52′ 50″ S.
Index correction	+ 1 5
	52 53 55
Dip (Norie)	— 3 19
App. alt. sun's L.L.	52 50 36
Corr. of alt.	— 38
True alt. sun's L.L.	52 49 58
Semi-diameter	+ 16 5
True altitude	53 6 3
	90 0 0
Zenith distance	36 53 57 N.
Declination	0 14 32 N.
Latitude	37 8 29 N.

Ex. 4. 1865, April 16th, longitude 139° 50′ E., observed meridian altitude sun's L.L. 89° 46′ 10″, bearing north; index correction, + 1′ 56″; height of eye 18 feet.

Ship date, April	16d 0h 0m 0s	
Long. 139° 50′ E.	— 9 19 20	
Greenwich date	15 14 40 40	

(In subt. long. in time borrow 24h.)
Decl. 15th, 9° 52′ 24″ N.
16th, 10 13 41 N.

Daily var.	21 17	log. 0522
Green. time	14h 41m	log. 2134
	13 1	log. 2656
	9 52 24 N.	
Red. decl.	10 5 25 N.	

By Raper: index corr., + 1′ 56″; dip, 4′ 10″; ref., &c., 0′; semid., + 15′ 58″; true alt. 89° 59′ 54″, latitude 10° 5′ 19″ N.

Obs. alt. sun's L.L.	89° 46′ 10″ N.
Index correction	+ 1 56
	89 48 6
Dip (Norie, Table 5.)	— 4 4
	89 44 2
Corr. alt. (Table 18.)	0 0 0
	89 44 2
Semi-diameter	+ 15 58
True altitude	90 0 0
	90 0 0
Zenith distance	0 0 0
Declination	10 5 25 N.
Latitude	10 5 25 N.

Ex. 5. 1865, July 13th, longitude 39° 52′ E., observed meridian altitude sun's L.L. 67° 59′ 40″, bearing north; index correction, — 38″; height of eye 17 feet.

Ship date, July	12d 24h 0m 0s	
Long. 39° 52′ E.	— 2 39 28	
Greenwich date	12 21 20 32	
Decl. 12th, 21° 57′ 9″ N.		
13th, 21 48 32 N.		
Daily var.	8 37	log. 4449
Green. time	21h 21m	log. 0508
	— 7 40	4957
	21 57 9	
Red. decl.	21 49 29 N.	

By Raper: index corr., — 38″; dip, — 4′ 5″; ref., — 0′ 24″; par., + 3″; semid., + 15′ 46″; true alt. 68° 10′ 22″; latitude 0° 0′ 9″ S.

Obs. alt. sun's L.L.	67° 59′ 40″ N.
Index correction	— 38
	67 59 2
Dip (Norie)	— 3 57
	67 55 5
Correction altitude	— 20
	67 54 45
Semi-diameter	+ 15 46
True altitude	68 10 31
	90 0 0
Zenith distance	21 49 29 S.
Declination	21 49 29 N.
Latitude	0 0 0

The ship is on the Equator.

Ex. 6. 1865, December 17th, longitude 175° 45′ W., observed meridian altitude sun's L.L. 89° 57′ 50″, bearing north, index correction + 4′ 17″, height of eye 24 feet.

Greenwich date $17^d\ 11^h\ 43^m$.		
Decl. 17th,	23° 22′ 54″ S.	
18th,	23 24 41 S.	
Daily var.	1 47	log. 1·1290
Green. time	$11^h 43^m$	log. 3114
	0 52	log. 1·4404
	23 22 54 S.	
Red. decl.	23 23 46 S.	

The true altitude by Raper's tables is 90° 13′ 35″, zenith distance 0° 13′ 51″ N. latitude 23° 10′ 11″ S.

Obs. alt. sun's L.L.	89° 57′ 50″ N.
Index correction	+ 4 17
	90 2 7
Dip (Table 5.)	− 4 42
	89 57 25
Corr. alt. (Table 18.)	0 0 0
	89 57 25
Semi-diameter	+ 16 18
True altitude	90 13 43 N.
Zenith distance	0 13 43 N.
Declination	23 23 46 S.
Latitude	23 10 3 S.

Ex. 7. 1865, September 23rd, longitude 163° 15′ E., observed meridian altitude sun's L.L. 40° 9′, bearing north; index correction + 20″, height of eye 18 feet.

Ship date, Sept.	$23^d\ 0^h\ 0^m 0^s$	
Long. 163° 15′ E.	− 10 53 0	
Greenwich date	22 13 7 0	
Decl. 22nd,	0° 12′ 47″ N.	
23rd,	0 10 37 S.	
Daily var.	23 24	log. 0110
Green. time	$13^h\ 7^m$	log. 2624
	12 47 S.	log. 2734
	0 12 47 N.	
Red. decl.	0 0 0	

By Raper, index corr., + 20″; dip, − 4′ 10″; ref., − 1′ 9″; par + 7″; semid. + 15′ 59″; true alt. 40° 20′ 7″; latitude 49° 39′ 53″ S.

Obs. alt. sun's L.L.	40° 9′ 0″ N.
Index correction	+ 20
	40 9 20
Dip	− 4 4
	40 5 16
Correction altitude	− 1 1
	40 4 15
Semi-diameter	+ 15 59
True altitude	40 20 14
	90 0 0
Zenith distance	49 39 46 S.
Declination	0 0 0
Latitude	49 39 46 S.

Ex. 8. 1865. August 23rd, longitude 168° 25′ W., observed meridian altitude sun's L.L. 40° 5′ 30″, observer N. of sun; index corr., — 54″; height of eye 12 feet.

Green. date Aug. $23^d\ 11^h\ 13^m\ 40^s$

Decl. 23rd, is 11° 22′ 6″ N., ditto 24th, 11° 1′ 35″ N., daily var. — 20′ 31″, corr. — 9′ 36″, *Red. decl.* 11° 12′ 30″ N.

By Norie: index corr. — 54″, dip — 3′ 19″, corr. of alt. 1′ 1″, semid. + 15′ 52″, *True alt.* 40° 16′ 8″.

True altitude	40° 16′ 8″
	90 0 0
Zenith distance	49 43 52 N.
Declination	11 12 30 N.
Latitude	60 56 22 N.

Ex. 9. 1866, January 1st, longitude 150° E., observed meridian altitude sun's L.L. 70° 20′ (zenith N. of sun); index corr. — 30″; height of eye 19 feet.

Green. date, 1865, Dec. $31^d\ 14^h\ 0^m\ 0^s$

Decl. Dec. 31st, 23° 5′ 3″ S., ditto 32nd 23° 0′ 16″ N., daily var. — 4′ 47″, corr. — 2′ 47″, *Red. decl.* 23° 2′ 16″ S.

By Norie: index corr. — 30″, dip — 4′ 11″, corr. alt. 0′ 18″, semid + 16′ 18″, *True alt.* 70° 31′ 19″.

True altitude	70° 31′ 19″
	90 0 0
Zenith distance	19 28 41 N.
Declination	23 2 16 S.
Latitude	3 33 35 S.

Examples for Practice.

In each of the following examples the latitude is required:—

No.	Civil Date.	Longitude.	Obs. Alt. Sun's L.L.	Index Corr.	Eye.
1.	1865, Jan. 10th,	49° 51′ W.	68° 39′ 40″ N.	+ 5′ 10″	13 ft.
2.	„ Feb. 1st,	39 51 E.	72 43 50 S.	+ 1 42	13
3.	„ March 8th,	89 48 E.	51 49 30 S.	− 3 17	15
4.	„ April 28th,	165 23 W.	U.L. 82 51 10 N.	+ 4 10	18
5.	„ May 2nd,	32 3 E.	U.L. 46 18 0 S.	0	20
6.	„ June 11th,	62 57 E.	L.L. 42 24 45 N.	+ 2 15	21
7.	„ July 20th,	156 38 W.	51 58 30 N.	− 2 39	16
8.	„ Aug. 19th,	82 30 W.	57 41 0 S.	− 1 3	22
9.	„ Aug. 26th,	92 3 E.	35 35 20 N.	+ 2 17	12
10.	„ Sept. 23rd,	166 30 E.	41 36 10 S.	− 4 41	17
11.	„ Oct. 23rd,	90 12 W.	54 40 40 S.	− 0 49	18
12.	„ Nov. 15th,	80 11 E.	67 43 0 S.	+ 1 38	15
13.	„ Dec. 10th,	55 20 E.	25 52 15 S.	+ 2 0	17
14.	„ Sept. 21st,	60 1 E.	56 26 0 N.	0	20
15.	„ March 21st,	144 0 E.	61 49 30 S.	− 3 17	15
16.	„ April 7th,	139 45 W.	89 55 50 S.	+ 5 10	12
17.	„ May 16th,	45 26 W.	86 34 19 N.	+ 4 16	15
18.	„ Sept. 23rd,	90 45 E.	83 40 30 S.	0	18
19.	„ Nov. 3rd,	106 0 E.	70 29 45 N.	+ 1 22	19
20.	„ Sept. 22nd,	173 58 W.	71 19 20 S.	+ 3 40	18
21.	„ Feb. 12th,	8 12 W.	29 55 20 S.	− 1 10	19
22.	„ March 20th,	29 30 W.	76 58 15 N.	− 2 20	21
23.	1866, Jan. 1st,	125 32 E.	U.L. 54 57 20 S.	+ 2 10	22
24.	1865, Oct. 1st,	71 20 E.	U.L. 82 0 15 N.	− 3 15	14

VARIATION BY AN AMPLITUDE.

The Variation is found by comparing the bearing of the sun or other celestial body, as shewn by the compass, with the true bearing, as found by calculation.

The True Amplitude is the bearing of a celestial body at rising or setting (*i.e.*, when its centre is on the *rational* horizon), from the *true* East or West point, found by calculation from the latitude of the place and declination of the body, or taken by inspection from a table, of which these quantities are the arguments (Table XLII, Norie, or LIX, Raper).

The Magnetic Amplitude is the bearing of a celestial body at rising or setting from the compass East or West points, found by direct observation with an instrument fitted with a magnetic needle, as the Azimuth Compass.

The magnetic amplitude is distinguished as *observed*, or *apparent*, and *corrected*. The *observed*, or apparent, magnetic amplitude of a celestial body is its bearing from the compass East or West point, when it appears in the sea-horizon of an observer standing on the deck of a ship. The *corrected* magnetic amplitude is the bearing of the body from the compass East or West point, when on the rational horizon, as it would appear to a spectator at the centre of the sphere through a uniform medium. The diurnal circles of the celestial bodies being, except at the equator, inclined to the horizon, and more and more the higher the latitude, any cause which affects the time of rising will affect the apparent amplitude, and in a greater degree as the latitude increases. The following are the causes:—(1) The elevation of the observer depresses the sea-horizon, while it does not affect the place of the celestial body—hence by reason of the *dip*, the body appears to rise before it is truly on the sensible horizon. (2) The great *refraction* at the horizon causes the body to appear to rise considerably before it comes to the sensible horizon. (3) When a body is in the sensible horizon, to an eye at the centre of the sphere it has already passed the rational horizon. This being the effect of *parallax*, is only of importance in the case of the moon. These corrections will be found in Table 59 A, Raper.

RULE L.

1°. *With the ship date and longitude in time, find the Greenwich date* (see Rule XLII, page 116).

The time of sunrise and sunset is generally given in apparent time.

2°. *Take out of* Nautical Almanac *the sun's declination for this date* (see Rule XLIII, page 119).

3°. *Take from the Tables the log. sine of declination, and log. secant of latitude (rejecting 10 from the index); the sum of these is log. sine of true amplitude, which take out of Tables.*

4°. *If the body is rising, or* A.M., *mark true amplitude* East; *if it is setting, or* P.M., *mark it* West: *mark it also* North, *when declination is* North; *or* South, *when declination is* South.

(a) *When the declination is* 0, *the true amplitude is* 0; *that is, it is* East *if the object is rising*—West *if it is setting.*

(b) *When the latitude is* 0, *the declination is the true amplitude.*

5°. *Under the true amplitude write the magnetic amplitude; then if they are both marked* North, *or both marked* South, *take their* difference; *but when* one *is marked* North, *and the* other South, *take their* sum: the result in either case, is the variation.

The magnetic amplitude must be reckoned from East or West towards the North or South, before it is placed underneath the true. Thus: the magnetic amplitude S.E. by E. ½ E. is E. 2½ points S., or E. 28° 7′ 30″ S.

6°. *The variation is named* East, *when the true amplitude is to the* right *of* magnetic *amplitude;* West *when* true *is to the left of* magnetic: the observer being supposed looking from the centre of the compass, in the direction of magnetic amplitude.

EXAMPLES.

Ex. 1. 1865, January 6th, at $4^h\ 44^m\ 27^s$ A.M. apparent time at ship, lat. 37° 59′ S., long. 36° 24′ W., the sun's magnetic amplitude S.E. by E. ½ E.; required the true amplitude and variation.

Ship date, Jan.	$5^d\ 16^h 44^m 27^s$	Decl. 5th,	22° 34′ 54″ S.	
Long. in time	+ 2 25 36	6th,	22 27 45 S.	
Greenwich date, Jan.	5 19 10 3		7 9	log. 5259
			$19^h\ 10^m$	log. 0977
			5 43	log. 6236
			22 34 54 S.	
		Red. decl.	22 29 11 S.	

	Declination	22° 29′ 11″	sine 9·582591
	Latitude	37 59 0	secant 0·103369
			sine 9·685960
(A.M. and S. decl.)	True amplitude E.	29° 1′ 42″ S.	
(S.E. by E. ½ E.)	Mag. amplitude E.	28 7 30 S. = E. 2½ points.	
	Variation	0 54 12 E., because *true* amplitude is to the *right* of *magnetic* amplitude.	

Ex. 2. 1865, February 16th, at $4^h\ 57^m\ 42^s$ P.M. apparent time at ship, latitude 51° 9′ N., longitude 16° 3′ W., sun's magnetic amplitude W. 8° 26′ N.; required the variation.

Ship date, Feb.	$16^d\ 4^h 57^m 42^s$	Decl. 16th,	12° 12′ 39″ S.	
Long. 16° 3′ W.	+ 1 4 12	17th,	11 51 41 S.	
Green. date, Feb.	16 6 1 54		20 58	log. 0587
			$6^h\ 2^m$	log. 5997
			5 16	log. 6584
			12 12 39 S.	
		Red. decl.	12 7 23 S.	

	Declination	12° 7′ 23″	sine 9·322245
	Latitude	51 9 0	secant 0·202536
			sine 9·524781
(P.M. and S. decl.)	True amplitude W.	19° 33′ 37″ S.	
	Mag. amplitude W.	8 26 0 N.	
	Variation	27 59 37 W., the *true* amplitude being to the *left* of *magnetic.*	

Ex. 3. 1865, April 13th, at $5^h\ 47^m\ 20^s$ A.M. apparent time at ship, latitude 20° 2′ N., longitude 107° 56′ E., sun's magnetic amplitude E. by N.

Ship date, April	$12^d\,17^h 47^m 20^s$	Decl. 12th,	$8^\circ 47' 34''$ N.	
Long. 107° 56′ E.	— 7 11 44	13th,	9 9 20 N.	
Green. date, April	12 10 35 36		21 46	log. 0424
			$10^h 36^m$	log. 3549
			9 37	log. 3973
			8 47 34 N.	
		Red. decl.	8 57 11 N.	

	Declination	$8^\circ 57' 11''$	sine	9·192080
	Latitude	20 2 0	secant	0·027106
			sine	9·219186
(A.M. and N. decl.)	True amplitude E.	$9^\circ 32' 6''$ N.		
(E. 1 point N.)	Mag. amplitude E.	11 15 0 N.		
	Variation	1 42 54 E., the *true* amplitude being to the *right* of *magnetic*.		

Ex. 4. 1865, June 10th, at $4^h 45^m$ P.M. apparent time at ship, latitude 36° 42′ S., longitude 120° 30′ E., magnetic amplitude N.W. ¾ W.

		(Page I, N.A.)		
Ship date, June	$10^d\ 4^h 45^m$	Decl. 9th,	$22^\circ 57' 52''$ N.	
		10th,	23 2 34 N.	
or June	9 28 45		4 42	log. 7081
Long. 120° 30′ E.	— 8 2		$20^h 43^m$	log. 0639
Green. date, June	9 20 43		4 3	log. 7720
			22 57 52 N.	
		Red. decl.	23 1 55 N.	

	Declination	$23^\circ 1' 55''$	sine	9·592448
	Latitude	36 42 0	secant	0·095947
			sine	9·688395
(P.M. and N. decl.)	True amplitude W.	$29^\circ 12' 27''$ N.		
(W. 3¼ N.)	Mag. amplitude W.	36 33 45 N.		
	Variation	7 21 18 W., because the *true* amplitude is to *left* of *magnetic*.		

Ex. 5. 1865, July 31st, at $4^h 26^m$ A.M. apparent time at ship, latitude 46° 3′ N., longitude 165° 58′ W., sun's magnetic amplitude E. 14° 4′ N.

The Greenwich date, July $31^d\ 3^h 29^m 52^s$.

Decl. 31st, 18° 13′ 15″ N.; and decl. 32nd, 17° 58′ 13″ N.; daily var. 15′ 2″; corr. — 2′ 12″; *Red. decl.* 18° 11′ 3″ N.

	Declination	$18^\circ 11' 3''$	sine	9·494255
	Latitude	46 3 0	secant	0·158622
			sine	9·652877
(A.M. and N. decl.)	True amplitude E.	$26^\circ 43' 17''$ N.		
	Mag. amplitude E.	14 4 0 N.		
	Variation	12 39 17 W., the *true* amplitude being to the *left* of *magnetic*.		

Ex. 6. 1865, Sept. 23rd, at $6^h\ 0^m$ A.M., apparent time at ship, latitude 24° 40′ S., longitude 73° 15′ E., sun's magnetic amplitude E. 10° 40′ S.

		(Page I, N.A.)	
Ship date, Sept.	$22^d\ 18^h\ 0^m$	Decl. 22nd, 0° 12′ 47″ N.	
Long. 73° 15′ E.	— 4 53	23rd, 0 10 37 S.	
Green. date, Sept.	22 13 7	23 24 S.	log. 0110
		$13^h\ 7^m$	log. 2624
		— 12 47 S.	log. 2734
		0 12 47 N.	
		0 0 0	

The declination being 0°, the true amplitude is 0° or E. 0° 0′, whence the variation is 10° 40′ W., because the *true* amplitude is to *left* of *magnetic.*

Ex. 7. 1865, Dec. 10th, at $8^h\ 27^m$ A.M. apparent time at ship, latitude 54° 35′ N., longitude 53° 15′ W., sun's magnetic amplitude S. by E.

Ship date, Dec.	$9^d\ 20^h\ 27^m$	Decl. at noon, 10th, 22° 57′ 23″ S.
Long. 53° 15′ W.	+ 3 33	
Green. date, Dec.	9 24 0	
or Dec.	10 0 0	

Declination	22° 57′ 23″	sine	9·591098
Latitude	54 35 0	secant	0·236933
		sine	9·828031
(A.M. and S. decl.) True amplitude E.	42° 18′ 3″ S.		
(E. 7 points S.) E.	78 45 0 S.		
Variation	36 26 57 W., the *true* amplitude being to the *left* of *magnetic.*		

Ex. 8. 1865, December 20th, at $4^h\ 31^m$ P.M. apparent time at ship, lat. 41° 12′ N., longitude 110° 45′ E., sun's setting amplitude S.W. by W.

The Greenwich date, December $19^d\ 21^h\ 8^m$.

Decl. noon 19th, 23° 26′ 0″ S.; decl. 20th, 23° 26′ 51″ S.; daily var. + 0′ 51″; corr. + 0′ 45″; *Red. decl.* 23° 26′ 45″ S.

Declination	23° 26′ 45″ S.	sine	9·599754
Latitude	41 12 0	secant	0·123543
		sine	9·723297
(P.M. and S. decl.) True amplitude W.	31° 55′ 30″ S.		
(W. 3 points S.) Mag. amplitude W.	33 45 0 S.		
Variation	1 49 30 E., the *true* amplitude being to the *right* of *magnetic.*		

Ex. 9. 1865, November 15th, at $6^h 45^m$ P.M. apparent time at ship, latitude 31° 56′ N. longitude 75° 30′ W., sun's setting amplitude W. 15° 40′ S.

The Greenwich date, November $15^d\ 11^h\ 47^m$.

Decl. noon 15th, 18° 34′ 37″ S.; decl. 16th, 18° 49′ 41″ S.; daily var. 15′ 4″: corr. + 7′ 24″; *Red. decl.* 18° 42′ 1″ S.

Declination	18° 42′ 1″ S.	sine	9·505987
Latitude	31 56 0	secant	0·071264
		sine	9·577251
(P.M. and S. decl.) True amplitude W.	22° 11′ 49″ S.		
Mag. amplitude W.	15 40 0 S.		
Variation	6 31 49 W., the *true* amplitude being to the *left* of *magnetic.*		

Ex. 10. 1865, July 20th, at $7^h\ 0^m$ P.M. apparent time at ship, latitude 34° 51′ S., longitude 172° 28′ E., sun's magnetic amplitude W. by N. ½ N.

The Greenwich date, July $19^d\ 19^h\ 30^m\ 8^s$.

Decl. 19th, 20° 49′ 6″ N.; decl. 20th, 20° 37′ 57″ N.; daily var. — 11′ 9″; corr. — 9′ 4″; *Red. decl.* 20° 40′ 2″ N.

Declination	28° 40′ 2″	sine	9·547700
Latitude	34 51 0	secant	0·085842
		sine	9·633542
(P.M. and N. decl.) True amplitude W.	25° 28′ 20″ N.		
(W. 1½ point N.) Mag. amplitude W.	16 52 30 N.		
Variation	8 35 50 E., the *true* amplitude being to the *right* of the *magnetic.*		

Ex. 11. 1865, May 6th, at $5^h\ 30^m$ A.M. apparent time at ship, latitude 50° 50′ N., longitude 47° 12′ E., sun's rising amplitude E. ¼ S.

The Greenwich date, May $5^d\ 14^h\ 21^m\ 12^s$.

Decl. 5th, 16° 20′ 10″ N.; decl. 6th, 16° 37′ 4″ N.; daily var. + 16′ 54″; corr. + 10′ 6″; *Red. decl.* 16° 30′ 16″ N.

Declination	16° 30′ 16″	sine	9·453455
Latitude	50 50 0	secant	0·199573
		sine	9·653028
(A.M. and N. decl.) True amplitude E.	26° 43′ 53″ N.		
(E. ¼ S.) Mag. amplitude E.	2 48 45 S.		
Variation	29 32 38 W., the *true* amplitude being to the *left* of *magnetic.*		

EXAMPLES FOR PRACTICE.

In each of the following examples the variation is required:—

NO.	CIVIL DATE.	APP. TIME.	LATITUDE.	LONGITUDE.	SUN'S MAG. AMP.
1.	1865, Jan. 27th,	$6^h 55^m 40^s$ A.M.	35° 42′ N.	12° 52′ W.	S.E.
2.	„ Feb. 17th,	6 48 0 P.M.	34 57 N.	40 8 E.	W.S.W.
3.	„ March 29th,	5 50 0 A.M.	25 50 S.	127 35 W.	E. by S. ¾ S.
4.	„ April 5th,	6 15 0 P.M.	20 20 S.	155 30 E.	W.
5.	„ March 5th,	6 22 0 A.M.	41 2 N.	22 0 W.	S.E. ¾ E.
6.	„ May 26th,	7 56 0 A.M.	51 22 S.	48 0 E.	E.
7.	„ June 2nd,	8 8 2 P.M.	52 30 N.	27 6 W.	N. by W. ¼ W.
8.	„ July 14th,	6 50 58 A.M.	28 59 S.	111 11 W.	N.E. ¾ E.
9.	„ Aug. 27th,	5 44 0 P.M.	21 4 S.	36 19 E.	N.W. by W.
10.	„ Sept. 8th,	5 47 0 A.M.	24 22 N.	57 30 W.	E.
11.	„ Oct. 1st,	5 48 50 A.M.	42 44 S.	175 15 W.	E. by N. ¼ N.
12.	„ Sept. 23rd,	6 0 0 A.M.	56 41 S.	73 15 E.	E.
13.	„ Nov. 3rd,	6 34 0 P.M.	29 20 S.	136 35 E.	W. by S. ¾ S.
14.	„ Dec. 4th,	7 56 48 P.M.	49 59 S.	160 45 E.	W. by S. ¾. S.
15.	„ March 20th,	6 0 0 P.M.	55 10 N.	60 32 E.	N. W. ½ W.
16.	„ Sept. 22nd,	6 0 0 P.M.	60 1 S.	106 45 W.	W.
17.	„ June 19th,	6 0 0 A.M.	0 0	10 21 W.	E. ½ N.
18.	„ Feb. 26th,	7 49 0 A.M.	62 5 N.	12 52 W.	S.S.E.
19.	„ April 30th,	6 28 12 P.M.	24 58 N.	138 52 W.	W. ½ N.
20.	„ May 27th,	7 40 0 P.M.	47 40 N.	148 3 W.	W. by. N.
21.	„ June 16th,	4 6 0 A.M.	47 30 N.	50 20 W.	E. 8° 26′ N.
22.	„ March 6th,	6 14 0 P.M.	31 24 S.	2 10 E.	W. 16° 52′ N.
23.	„ Oct. 1st,	5 49 0 A.M.	42 10 S.	45 33 E.	E. by S.
24.	„ June 1st,	3 52 0 P.M.	52 30 S.	24 50 W.	W. by N. ¼ N.

ON FINDING THE TIME OF HIGH WATER.

IN the Nautical Almanac the mean time of high water at London Bridge is given for every day of the year, on the assumption that the time of high water on the days of full and change, or as it is termed, the ESTABLISHMENT OF THE PORT (see Nautical Almanac for 1865, page 488) is $2^h\ 7^m$. The first high water which occurs after mean noon of each day is inserted in the first column, and the second in the second column. Where a line (——) is inserted, it indicates that there is only *one* high water on that day. Thus, on 1865, January 8th, there is only one high water: it occurs January 8th, at $11^h\ 33^m$ (P.M.); but the succeeding high tide does not take place until $0^h\ 6^m$ after mean noon January 9th. The time given, it will be observed, is expressed in astronomical time. Again, on February 7th, 1865, there is only one high tide: it occurs at February $7^d\ 12^h\ 28^m$ astronomical time; *i.e.*, $12^h\ 28^m$ past the noon of

the 7th, which is $0^h\ 28^m$ past midnight, or expressed in civil time it is February $8^d\ 0^h\ 28^m$ A.M. Immediately following the Table just referred to, is another in which is registered the Establishment for nearly one hundred important stations (pages 490 and 491), under the heading "Time of High Water on the Full and Change of the Moon." Hence may be deduced the time of high water for any day at the given place.

FIRST METHOD.—By Nautical Almanac.

RULE LI.

1°. *Take out of* Nautical Almanac (page 490, for 1865) *the establishment of the port, or the time of high water on the full and change of the moon, at the* given place *and* also *at* London Bridge.

2°. *Take the* difference *of these two quantities, and mark it* + *when the establishment of port at the* given place *is* more *than that at* London Bridge, *but mark the difference* — *when the establishment of port at the* given place *is* less *than at* London Bridge.

3°. *Take the times of high water at* London Bridge *for the* given day *from the* Nautical Almanac (pages 488, 489, for 1865.)

The morning tide is found in the second column and opposite the preceding day of the month, the time thus given being diminished by 12^h. The afternoon tide is found in the first column, opposite the given day of the month. If a blank occurs in either column, use the tide *preceding* instead when the difference found by Rule 2° is marked +, but use the tide *following* the blank when the difference is marked —. Be sure to annex the letters A.M. or P.M. to the tides so taken out.

4°. *To the times of high water at* London Bridge *apply the* difference, or constant, adding *or* subtracting *said* difference *according as it is marked* + *or* — *;* the result in each case, *if* less *than* 12^h, *is the* A.M. and P.M. *tides respectively.*

(a) *When the* sum *of the* constant *and the* A.M. London Bridge *tide* exceeds 12^h, deduct 12^h; *the* remainder *is* P.M. *tide at the given place. To obtain the* A.M. *tide at the place, if any,* add *the* constant *to the* London Bridge *tide preceding, that is, the afternoon tide of the day before; or* if *the* sum is less than 12^h, it is the P.M. tide of the day before, and there is no A.M. tide that day at the given place; but if the sum *exceeds* 12^h, deduct 12^h, the remainder is A.M. tide sought.

(b) *When the constant* added *to London* A.M. *tide is* less *than* 12^h, *but when* added *to London* P.M. *tide preceding* exceeds 12^h *there is only an* A.M. tide *at the given place on that day.*

(c) *When the constant is* subtractive *and* exceeds *the* London A.M. *tide,* reject *this last, and use the* P.M. London *tide following. If the* constant *being* subtractive exceeds London P.M. tide, 12^h *must be* added *to this last before* subtraction *is made; the* remainder *will be* A.M. *tide at given place. For the* P.M. *tide use the* following London tide, *that is the* morning tide *of* next day, *borrowing* 12^h *if constant* exceeds *it, the* remainder *is* P.M. *tide at given place.*

(d) If constant being subtractive exceeds *the* London A.M. *tide, but is less than the* London P.M. *tide, there is only a* P.M. *tide at the given place on that day.*

(e) *If when* constant *is subtractive the London* P.M. tide *has to be* increased 12^h, *but* constant *is* less *than the* London A.M. tide following: *there is* only an A.M. tide *at the given place that day.*

EXAMPLES.

Ex. 1. 1865, January 11th: required the times of high water at Shields, A.M. and P.M.

Establishment of Port at Shields, page 491, N.A.	$3^h 23^m$
" " London Bridge	2 7
Difference +	1 16

Time H. W. London Bridge, Jan. 10th, $13^h 32^m$, or 11th,	$1^h 32^m$ A.M.	Time H.W. London Bridge, 11th	$1^h 55^m$ P.M.
Difference +	1 16	Difference +	1 16
Time H.W. Shields, 11th ..	2 48 A.M.	Time H. W. Shields, 11th,	3 11 P.M.

Ex. 2. 1865, February 15th: find the times of high water at Chatham, A.M. and P.M.

Establishment of Port at Chatham........	$1^h 2^m$
" " London Bridge ..	2 7
Difference —	1 5

Time H. W. London Bridge, Feb. 14th, $16^h 48^m$, or ..	$4^h 48^m$ A.M.	Time H. W. London Bridge, 15th	$5^h 3^m$ P.M.
Difference —	1 5	Difference —	1 5
Time H. W. Chatham, 15th	3 43 A.M.	Time H. W. Chatham, 15th	3 58 P.M.

Ex. 3. 1865, March 6th: find the A.M. and P.M. tides at Liverpool (St. George's Pier).

Establishment of Port, Liverpool Dock....	$11^h 23^m$
" " London Bridge....	2 7
Difference +	9 16

Time H. W. London Bridge,
5th, $20^h\ 37^m$, or 6th .... $8^h 37^m$ A.M.
Difference + 9 16

17 53
— 12 0

Time H. W. Liverpool, 6th 5 53 P.M.

To find the A.M. tide at Liverpool we must use the preceding London Bridge tide,—viz., that from the first column on the 5th, thus:—

Time H. W. London Bridge,
5th.................... $8^h\ 0^m$ P.M.
Difference + 9 16

17 16 P.M.
— 12 0

Time H. W. Liverpool, 6th 5 16 A.M.

Ex. 4. 1865, June 21st: find the times of high water at Beaumaris, A.M. and P.M.

Establishment of Port, Beaumaris .... $10^h 32^m$
" " London Bridge 2 7

Difference + 8 25

Time H. W. London Bridge,
20th, $11^h\ 43^m$ .... $11^h 43^m$ P.M.
Difference + 8 25

Time H. W. Beaumaris, 20th 20 8 P.M.
— 12 0

Or 21st, 8 8 A.M.

For the P.M. tide at Beaumaris, take out the tide opposite the given date and in the first column, thus:—

Time H. W. London Bridge
(first column) 21st ...... $0^h 14^m$ P.M.
Difference + 8 25

Time H. W. Beaumaris, 21st 8 39 P.M.

The second column opposite the preceding date, which is the one usually taken out, being *blank*, and the *difference* being marked +, we must use the preceding tide as above.

Ex 5. 1865, May 22nd: find the times of high water at Greenock.

Establishment of Port, Greenock .... $0^h\ 8^m$
" " London Bridge. 2 7

Difference — 1 59

Time H. W. London Bridge,
21st, $23^h\ 40^m$, or 22nd .. $11^h 40^m$ A.M.
Difference — 1 59

Time H. W. Greenock, 22nd, 9 41 A.M.

Time H. W. London Bridge,
22nd, $12^h\ 9^m$............ $12^h\ 9^m$ P.M.
Difference — 1 59

Time H. W. Greenock, 22nd, 10 10 P.M.

The first column opposite the given day being *blank*, the next tide is employed.

Ex. 6. 1865, May 8th: find the times of high water at Dunkerque, A.M. and P.M.

Establishment of Port, Dunkerque .... $0^h\ 8^m$
" " London Bridge 2 7

Difference — 1 59

The time of H. W. at London Bridge on the morning of the 8th is $0^h\ 32^m$, whence it is evident, if we subtract from it the difference above, viz., $1^h\ 59^m$, the remainder is P.M. of the 7th; we must therefore employ the P.M. London Bridge tide, borrowing $+\ 12^h$, in order to enable us to complete the subtraction, thus:—

Time H. W. London Bridge,
8th, $+\ 12^h$ .... $12^h 51^m$ P.M.
Difference — 1 59

Time H. W. Dunkerque 8th 10 52 A.M.

We now use, in order to find the afternoon tide at Dunkerque, the tide found in the second column and opposite the given day, thus:—

Time H. W. London Bridge,
8th, $13^h\ 33^m$, or 9th .... $1^h 11^m$ A.M.
Difference — 1 59

Time H. W. Dunkerque, 8th 11 12 P.M.

Ex. 7. 1865, July 20th: find the A.M. and P.M. tides at Tay Bar.

Establishment of Port, Tay Bar .... $2^h\ 6^m$
" " London Bridge 2 7

Difference — 0 1

Time H. W. London Bridge,
July 20th .... $0^h\ 2^m$ P.M.
Difference — 0 1

Time H. W. Tay Bar, 20th 0 1 P.M.

There is no morning tide at London Bridge, a blank occurring in that column. It is evident there is also no A.M. tide at Tay Bar.

Ex. 8. 1865, December 29th: find the times of high water at the Downs Stream, A.M. and P.M.

Establishment of Port, Downs .... $2^h 30^m$
" " London Bridge 2 7

Difference + 0 23

Time H. W. London Bridge,
Dec. 28th, $23^h\ 10^m$, or 29th $11^h 10^m$ A.M.
Difference + 0 23

Time H. W. Downs, 29th 11 33 A.M.

Time H. W. London Bridge,
Dec. 29th .... $11^h 44^m$ P.M.
Difference + 0 23

Time H. W. Downs, 29th.. 12 7 P.M.
30th.. 0 7 A.M.

Whence there is no P.M. tide, as it flows past midnight ($12^h\ 7^m$ P.M.)

Ex. 9. 1865, November 15th: find the A.M. and P.M. tides at Dunbar.

Establishment of Port, Dunbar .... $2^h\ 8^m$
" " London Bridge 2 7

Constant + 0 1

Time H. W. London Bridge,
14th, $11^h\ 53^m$ P.M. ...... $11^h 53^m$ P.M.
Constant + 0 1

Time H. W. Dunbar, 14th.. 11 54 P.M.
No A.M. tide.

Time H. W. London Bridge,
15th.................. $0^h 18^m$ P.M.
Constant + 0 1

Time H. W. Dunbar, 15th 0 19 P.M.

A blank occurring in the second column of the preceding date, and the constant being *additive*, the tide preceding the blank is employed to find the A.M. tide, but since the sum of constant and London tide does not amount to 12^h, it gives the P.M. tide at given place on preceding day, whence it is evident there is only a P.M. tide on that day at the given place.

EXAMPLES FOR PRACTICE.

In each of the following examples it is required to find the times of high water, A.M. and P.M. :—

NO.	CIVIL DATE.	PLACE.	NO.	CIVIL DATE.	PLACE.
1.	1865, Jan. 6th,	Brielle.	11.	1865, Nov. 19th,	Needles Point.
2.	„ Feb. 21st,	Goree West Gat.	12.	„ July 22nd,	Dunkerque.
3.	„ Mar. 16th,	Arundel Bar.	13.	„ June 6th.	Montrose.
4.	„ April 21st,	Cork Harbour.	14.	„ July 20th,	Dublin Bar.
5.	„ May 23rd,	Cuxhaven.	15.	„ Nov. 17th,	Greenock.
6.	„ April 7th,	Tay Bar.	16.	„ Mar. 1st,	Aldborough.
7.	„ Feb. 25th,	Nieuport.	17.	„ Mar. 1st,	Aberdeen.
8.	„ July 16th,	Sunderland.	18.	„ Nov. 1st,	Burntisland.
9.	„ Aug. 31st,	Harwich.	19.	„ Nov. 5th,	Caldy Island.
10.	„ Oct. 30th,	Hull.	20.	„ July 1st,	Newport.

SECOND METHOD.—By Admiralty Tide Tables.

THESE Tables published annually, give the *time* (A.M. and P.M.) of *high water*, and the *height of tide* for *every day in the year* at the following places, viz. :—*Brest, Devonport, Portsmouth, Dover, Sheerness, London, Harwich, Hull, Sunderland, North Shields, Leith, Thurso, Greenock, Liverpool, Pembroke, Weston-super-Mare, Holyhead, Kingston, Belfast, Londonderry, Sligo Bay, Galway, Queenstown, and Waterford.*

Thus, wishing to know the time of high water at Devonport on the morning of October 9th, 1864,—on turning to "*November*," under the head of "*Devonport*," it is seen at a glance that high water takes place at $10^h\ 49^m$ A.M., and that the *height* of tide is 12 feet 9 inches *above the mean low water level of spring tides.* Similarly, desiring to know the particulars of the tide at Brest on the morning of November 16th, 1864, the mark —— shows that no tide occurs in the morning of that day; there will be a high water at $11^h\ 32^m$ P.M. on the 10th, and again at $0^h\ 8^m$ P.M. (*i.e.*, 8^m past noon) of the 11th, but none in the interval.

RULE LII.

If the place at which the time of high water is required be not a standard port, *it is to be referred (if in the west of Europe) to a* standard port, *by* adding or subtracting *a certain* constant *to the time of that standard port, as directed in the Tables.*

In pages 103 to 108 of the Admiralty Tables, 1864, will be found upwards of two hundred ports on the coasts of the United Kingdom, and in Europe, for which standard ports of reference are given, and the time which is to be added to or subtracted from the time of high water at such standard port.

Examples.

Ex. 1. 1864, October 11th: find the times of high water, A.M. and P.M. at Needles Point.

Port of reference—Portsmouth	$7^h\ 19^m$ A.M.	$7^h\ 57^m$ P.M.
Constant for Needles	— 1 55	— 1 55
Times H.W. Needles, Oct. 11th,	5 24 A.M.	6 2 P.M.

Ex. 2. 1864, October 8th: find times of high water, A.M. and P.M., at Bordeaux.

Port of reference—Brest, H. W. Nov. 8th,	$8^h\ 8^m$ A.M.	$8^h\ 41^m$ P.M.
Constant for Bordeaux	+ 3 3	+ 3 3
Times H. W. Bordeaux, Nov. 8th	11 11 A.M.	11 44 P.M.

Ex. 3. 1864, October 10th: find times of high water, A.M. and P.M., at Cherbourg.

Port of reference—Brest, H. W. Oct. 10th,	$10^h\ 49^m$ A.M.	9th, $10^h\ 3^m$ P.M.
Constant for Cherbourg	+ 4 2	+ 4 2
	14 51	14 5
	— 12 0	— 12 0
Times H. W. Cherbourg, October 8th	2 51 P.M.	2 5 A.M.

Since by *adding* the constant to the morning tide at *Brest* it becomes P.M. tide at Cherbourg, we must employ the P.M. tide at Brest of the day before to find the A.M. tide at Cherbourg.

Ex. 4. 1864, October 8th: find A.M. and P.M. tides at Portland Breakwater.

In this case the standard port of reference is Portsmouth; and the first tide at Portsmouth occurs at $3^h\ 37^m$ A.M. (*i.e.*, $3^h\ 37^m$ after midnight), consequently, since Portland constant shows that the tide there occurs $4^h\ 40^m$ earlier than at Portsmouth, and that *quantity* subtracted from October $8^d\ 3^h\ 37^m$ A.M. would give a P.M. tide of the 7th at Portland; therefore we use Portsmouth tide of the 8th P.M. and of the 9th A.M., thus—

Time H. W. Portsmouth, Oct. 8th ..	$4^h\ 5^m$ P.M.	9th, $4^h\ 37^m$ A.M.
	+ 12 0	+ 12 0
	16 5	16 37
Constant for Portland	— 4 40	— 4 40
Times H. W. Portland B'kwater, 8th	11 25 A.M.	8th, 11 57 P.M.

In each case 12^h is borrowed to enable the subtraction to be completed.

Ex. 5. 1864, October 10th: find A.M. and P.M. tides at Falmouth.

The standard port of reference is Devonport. A blank (—) occurs in the morning column of the 10th, we therefore use the next tide (as the constant is subtractive), viz., the P.M. tide, 12^h being added to enable us to complete the subtraction, thus:—

Time H. W. Devonport, Oct. 10th,	$0^h\ 13^m$ P.M.	(next tide) 11th, $0^h\ 58^m$ A.M.
	+ 12 0	Constant — 0 46
	12 13	11th, 0 12 A.M.
Constant for Falmouth	— 46	
Times H. W. Falmouth, Oct. 10th,	11 27 A.M.	

Hence there is no P.M. tide on the 10th at Falmouth.

Ex. 6. 1864, July 18th: find the A.M. and P.M. tides at Flushing.

Time H. W. Dover, July 18th	$9^h 57^m$ A.M.	17th, $9^h 30^m$ P.M.
Constant for Flushing	+ 2 8	+ 2 8
	12 5	17th, 11 38 P.M.
	− 12 0	No morning tide on July 18th.
Time H. W. Flushing, July 18th	0 5 P.M.	

Ex. 7. 1864, August 26th: find A.M. and P.M. tides at Milford Haven (entrance),

Time H. W. Pembroke, 26th,	$0^h 15^m$ A.M.	27th, $0^h 55^m$ P.M.
Constant	− 20	− 20
	No A.M. tide.	26th, 0 35 P.M.

Ex. 8. 1864, December 30th: find A.M. and P.M. tides at Ramsey.

Time H. W. Holyhead, 30th,	$10^h 53^m$ A.M.	30th, $11^h 13^m$ P.M.
Constant	+ 1 1	+ 1 1
Time H. W. Ramsey, 30th,	11 54 A.M.	12 14
		31st, 0 14 A.M.

No P.M. tide at Ramsey.

Examples for Practice.

In each of the following examples it is required to find the times of high water, A.M. and P.M. :—

NO.	CIVIL DATE.	PLACE.	NO.	CIVIL DATE.	PLACE.
1.	1864, Jan. 11th,	Cherbourg.	13.	1864, Dec. 8th,	Padstow.
2.	„ Feb. 15th,	Aberdeen.	14.	„ Sept. 19th,	Needles Point.
3.	„ Mar. 17th,	Tynemouth Bar.	15.	„ Aug. 28th,	Dundee.
4.	„ Mar. 28th,	Yarmouth Roads.	16.	„ July 12th,	Bordeaux.
5.	„ May 30th,	Flambro' Head.	17.	„ April 18th,	Gibraltar.
6.	„ Nov. 5th,	Stromness.	18.	„ July 1st,	Falmouth.
7.	„ Aug. 11th,	Limerick.	19.	„ July 20th,	Beachy Head.
8.	„ Aug. 12th,	Sligo.	20.	„ Sept. 4th,	Beaumaris.
9.	„ Nov. 1st,	Dublin Bar.	21.	„ July 11th,	Swansea.
10.	„ Dec. 21st,	Cardiff.	22.	„ June 26th,	Wexford.
11.	„ Dec. 23rd,	Lundy Island.	23.	„ June 21st,	Douglas (I. Man).
12.	„ Aug. 5th,	Southampton.	24.	„ April 14th,	King's Road.

TO FIND THE TIME OF HIGH WATER AT FOREIGN PORTS.

In pages 149 to 202, of Admiralty Tide Tables for 1864, are given the times of high water at full and change, by which we are enabled to calculate approximately the time of high water on each day. The constant is found by taking Brest as the standard port, at which place the time of high water, full and change, is $3^h 47^m$. The difference between the full and change at the given port and Brest will be the constant, to be employed as in the preceding Rules, except if there be a great

difference of longitude; in which case the correction for the moon's meridian passage must be employed, since for the greatest longitude this correction may amount to half an hour. Should the longitude, however, not exceed 5°, it may be neglected, as doing so will scarcely make more than a difference of one minute. It must also be observed that the longitude of Brest is about $4\frac{1}{2}°$ W. of Greenwich, and in strictness, therefore, in determining this correction 4° should be subtracted, if the longitude of the place be east; or added if it be west. The correction is found in Table XVI, Norie, or Table XXVIII, Raper.

Examples.

Ex. 1. 1864, January 2nd: required the times of high water at Victoria River, longitude 130° E.

Time of H. W. full and change, Victoria River,	$7^h 15^m$
" " Brest........	3 47
Constant +	3 28

☽'s Transit, 2nd, $5^h 47^m$ A.M.	Long. Victoria River 130° E.
1st, 5 4	− 4
43	126 E.

Under 43^m and against 130° longitude, in Raper, Table 28, or Norie, 16, we find 15^m to be subtracted, because the longitude is E.

Time H. W. at Brest, 2nd,	$8^h 37^m$ A.M.
Constant +	3 28
	12 5
Correction for longitude −	0 15
Time H. W. at Victoria River, 2nd, ...	11 50 A.M.
No P.M. tide.	

Time H. W. Brest, 14th, ..	$9^h\ 3^m$ P.M.
Constant +	3 28
	12 31
Correction for longitude −	0 15
	12 16 P.M.
Time H. W. at Victoria River, 3rd	0 16 A.M.

Ex. 2. 1864, November 5th: find the times of high water at Sandy Hook, longitude 74° W.

Time of H. W. full and change, Sandy Hook	$7^h 29^m$
" " Brest	3 47
Constant +	3 42

☽'s Transit, 5th, $4^h 51^m$	Long. Sandy Hook, 74° W.
6th, 5 44	+ 4
53	78 W.

53^m and longitude 74° give correction 11^m, to be *added* because longitude is W.

Time H. W. Brest, 5th	$7^h\ 1^m$ A.M.	Time H. W. Brest, 5th	$7^h 29^m$ P.M.
Constant +	3 42	Constant +	3 42
	10 43		11 11
Correction for longitude +	11	Correction for longitude +	11
Time H. W. Sandy Hook, 5th	10 54 A.M.	Time H. W. Sandy Hook, 5th	11 22 P.M.

Ex. 3. 1864, July 2nd: required the times of high water at Nelson, New Zealand, longitude 173° E.

Time of H. W. full and change, at Nelson	$9^h 50^m$
" " Brest	3 47
Constant +	6 3

☽'s Transit, 2nd, $10^h 46^m$ A.M.
1st, 9 54
52

Under 52^m and opposite 169° in Table 16, Norie, or 27, Raper, stands correction 24^m to be *subtracted*.

Time H. W. Brest, 2nd	$2^h 23^m$ A.M.	Time H. W. Brest, 2nd	$2^h 45^m$ P.M.
Constant +	6 3	Constant +	6 3
	8 26		8 48 P.M.
Correction for longitude —	24	Correction for longitude —	24
Time H. W. at Nelson, 2nd	8 2 A.M.	Time H. W. at Nelson, 2nd	8 24 P.M.

Ex. 4. 1864, August 4th: find times of high water at Cape Virgin, Strait of Majellan, longitude 68° W.

Time of H. W., full and change, Cape Virgin ..	$8^h 30^m$
Brest	3 47
Constant +	4 43

☽'s Transit, 4th, $1^h 22^m$
5th, 2 4
42

42^m and long. 72° W., give corr. + 8^m.

Time H. W. at Brest, 4th, ..	$4^h 40^m$ A.M.	Time H. W. at Brest, 4th, ..	$4^h 55^m$ P.M.
Constant +	4 43	Constant +	4 43
	9 23		9 38
Correction for longitude .. +	8	Correction for longitude +	8
Time H. W. Cape Virgin, 4th,	9 31 A.M.	Time H. W. Cape Virgin, 4th,	9 46 P.M.

Examples for Practice.

Ex. 1. 1864, July 22nd: find the times of high water at Caracas River, Ecuador, longitude 67° W.

Ex. 2. 1864, September 29th: find the times of high water at Auckland, New Zealand, longitude 175° E.

Ex. 3. 1864, September 12th: find the times of high water at Point de Galle longitude 80° E.

Ex. 4. 1864, August 27th: find the times of high water at San Francisco Bay, longitude 122° W.

THIRD METHOD.—(Required by the Local Marine Board at Aberdeen.)

Given the apparent time of change tide, and the longitude of the place, to find the mean time of high water, A.M. and P.M.

RULE LIII.

1°. *Take out of the Nautical Almanac the* moon's *meridian passage on the* given *day, and also on the* preceding *day; also the moon's semi-diameter, and equation of time, for the given day (roughly).*

2°. *Under head* (1, 2, *and* 3, see examples) *put down the following quantities:—*

Under 1. *The time of moon's meridian passage on proposed day, as found in the Nautical Almanac.*

,, 2. *Put down half the sum of these times* (see examples).

,, 3. *The meridian passage on preceding day.*

3°. *Correct quantity* (1) *by* Table XVI, Norie), *by entering with longitude of place at top, and difference of times under* (1) *and* (3) *at the side; thus find the time of moon's meridian passage at the place. Take out the corrections from Table* (XXIX, Norie) *and place it under* (1). *This correction is found as follows:—Enter the Table at top with moon's semi-diameter, and at the side with moon's meridian passage, under* (1) corrected *by equation of time to nearest minute, so as to reduce time of moon's meridian passage, which is given in* mean time *to* apparent time.

4°. *Apply the correction thus found with its proper* sign, *and to the given result* add *the given apparent time of change tide.*

(a) *When the quantity under* (1) *is* less *than* 12 *hours.*

The time thus found is the mean time *of high water,* P.M., *for the proposed day* (see example 1).

(b) *When the quantity under* (1) *is* greater *than* 12 *hours, and* less *than* 24 *hours.*

Work as described above, with meridian passage under (2). *Then if the result is* greater than 12 *hours, reject* 12 *hours: the remainder is* mean time *of high water on the proposed day* P.M., (see example 2). *But if the result be* less *than* 12 *hours, it will be* mean time *of high water* A.M. *on the proposed day* (see example 5).

(c) *When the quantity under* (1) *is* greater *than* 24 *hours.*

Work as described above, with the meridian passage under (3). *Then if the result be* greater *than* 24 *hours, reject* 24 *hours: the remainder will be*

the mean time *of high water* P.M. *on the proposed day* (see example 4). *But if the result be* less *than* 24 *hours, and* greater *than* 12 *hours,* reject 12 *hours: the remainder will be the* mean time *of high water* A.M. *on the proposed day* (see example 5).

To find the next time of high water A.M. or P.M. If the time of high water found as above is the P.M. time, subtract therefrom the difference between the meridian passages under (1) and (2); the remainder will be the mean time of high water A.M. on the proposed day.

5°. *If the time of high water is the* A.M. *time,* add *thereto the* difference *between the meridian passages under* (1) *and* (2), *and the* sum *will be the mean time of high water* P.M. *on the proposed day.*

6°. *If it be necessary to add* 12 *hours before this* difference *can be* subtracted, *in that case the* remainder *will be the mean time of high water* P.M. *on the preceding day; there will be* no high water A.M. *on the proposed day. And if in* adding *the* difference *the* sum *be* greater *than* 12 *hours, this sum, rejecting* 12 *hours, will be the mean time of high water* A.M. *on the* following *day; there will be* no P.M. *on the proposed day.*

Examples.

Ex. 1. 1865, January 6th: find the times of high water, A.M. and P.M., at Shields, longitude $1° 25'$ W., change tide $3^h 23^m$.

☽'s mer. passage, or transit, Jan. 6^d $7^h 43^m$
5 6 50
2)0 53
26
7 17

☽'s semid. midnight, 6th, $15' 51''$.
Eq. time 6^m.
Sub. from mean time.

(1)		
☽'s mer. passage	6^d	$7^h 43^m$
Long. 1° and 53^m (T. 16) ..		0
	6	7 43

(2) $7^h 17^m$ (3) $6^h 50^m$

Mean time $7^h 43^m$
Eq. time — 6
App. time 7 37

$7^h 37^m$ and ☽'s semid. $15' 51''$ (Table 16) give........	—	11
	6	7 32
Establishment	+ 3	23
Time H. W. Shields	6	10 55 P.M.
Half daily change	—	26
Time H. W. Shields	6	10 29 A.M.

Ex. 2. 1865, October 31st: find the times of high water, A.M. and P.M. at Halifax, long. 64° W., change tide 8^h.

☽'s mer. passage or transit, Oct.	31^d	$9^h 32^m$	☽'s semid. midnight, 16′ 37″.
	30	8 38	Eq. time 16^m.
		2)0 54	*Added* to mean time.
		27	

(1)
☽'s mer. passage .. $9^h 32^m$
64° W. and 54^m (T. 16) + 9
M. T. transit at ship 9 41

(2)
9^h 5^m
+ 9
9 14

(3)
8^h 38^m

Mean time $9^h 14^m$
Eq. time + 16
App. time 9 30
9^h 30^m and ☽'s semid. 16′ 37″ + 36
9 50
Change tide .... + 8 0
17 50
— 12 0

Time H. W. Halifax	31	5 50	P.M.
Half daily change	—	0 27	
Time H. W. Halifax	31	5 23	A.M.

Ex. 3. 1865, October 31st: find times of high water, change tide 2^h 2^m, long. 60° E.

☽'s mer. passage, or transit, October	31^d	$9^h 32^m$	☽'s semid. midnight, 16′ 37″
	30	8 38	Eq. time 16^m.
		2)0 54	*Added* to mean time.
		27	

(1)
☽'s mer. passage 31^d $9^h 32^m$
54^m and long. 60° E. (Table 16) ...... — 9
M.T. transit at ship 31st 9 23
Mean time $9^h 23^m$
Eq. time + 16
App. time 9 39
9^h 39^m and ☽'s semid. 16′ 37″ (Table 29) + 36
9 59
Change tide + 2 2
12 1
Greater than 12 hours.

(2)
9^h 5^m
— 9
8 56
$8^h 56^m$
+ 16
9 12
9^h 12^m and 16′ 37″ (Table 29) .. + 34
9 30
2 2
Time H. W. 31 11 32 A.M.
½ daily change + 27
Time H. W. 31 11 59 P.M.

(3)
8^h 38^m

X

Ex. 4. 1865, July 21st: find times of high water, change tide $5^h\ 0^m$, long. 31° W.

☽ 's mer. passage, July $21^d\ 23^h 48^m$
20 22 56
2)0 52
26
23 22

☽ 's semid. noon 22nd, 15′ 27″.
Equation time 6^m.
Subtract from mean time.

(1)

☽ 's mer. passage, 21st (2) $23^h 48^m$
52^m and long. 31° W. (Table 16.) ...... + 4
23 52

Mean time $23^h 52^m$
Eq. time — 6
App. time 23 46
$23^h 46^m$ and ☽'s semid 15′ 27″ (Table 16*) + 3
23 55
Change tide.. + 5 0
28 55

Greater than 24 hours.

(3)

☽ 's mer. passage, 20th .. $22^h 56^m$
52^m and long. 31° W. (T. 16) + 4
23 0

Mean time $23^h\ 0^m$
Eq. time — 6
App. time 22 54
$22^h\ 54^m$ and 15′ 27″ (T. 16*) + 14
23 14
Change tide .... + 5 0
28 14
July 21st, 4 14 P.M.
— 26
July 21st, 3 48 A.M.

Ex. 5. 1865, March 8th: find the times of high water, change tide $2^h\ 18^m$ P.M. apparent time, longitude 70° E.

☽ 's mer. passage, or transit Mar..... $8^d\ 9^d 36^m$
7 8 49
2)0 47
23

☽ 's semid. midnight, 14′ 56″.
Eq. time 11^m.
Subtract from mean time.

(1)

☽ 's mer. passage, 8th .... $9^h 36^m$
47^m and long. 70° E. (T. 16) — 9
M. T. transit at ship, 8th.. 9 27
M. T. $9^h 27^m$
Eq. T. — 11
A. T. 9 16
$9^h\ 16^m$ and ☽'s semid. 14′ 56″, (T. 29) ...... + 20
9 47
Change tide .... + 2 18
12 5

Greater than 12 hours.

(2)

$9^h 13^m$
— 9
9 4
M. T. $9^h\ 4^m$
Eq. T. — 11
A. T. 8 53
$8^h 53^m$ & 14′ 56″ + 18
9 22
+ 2 18
Mar. 8th 11 40 A.M.
½ dly. ch. + 23
12 3
Mar. 9th 0 3 A.M.
No P.M. on Mar. 8th.

(3)

$8^h\ 49^m$

EXAMPLES FOR PRACTICE.

Required the times of high water in each of the following examples:—

1.	1865, July 29th,	long. 75° E.	change tide	$5^h 30^m$	P.M.	app. time.
2.	„ August 8th,	long. 40 W.	„	4 33	P.M.	„
3.	„ May 2nd,	long. 20 W.	„	6 40	P.M.	„
4.	„ May 22nd,	long. 120 E.	„	3 40	P.M.	„
5.	„ July 2nd,	long. 90 W.	„	5 30	P.M.	„
6.	„ June 19th,	long. 70 W.	„	2 40	P.M.	„

FINDING THE LONGITUDE BY CHRONOMETER.

GREENWICH DATE.

WHEN the error of a chronometer on Greenwich mean time, and also its daily rate, are known, we may determine Greenwich mean time at some other instant, as when an observation is taken, by the following:—

RULE LIV.

1°. *To the time by chronometer apply the original error,* adding *it if the chronometer was* slow, *rejecting* 24^h *if* greater *than* 24^h, *and putting the day one forward; but if chronometer is* fast, subtract *original error,* increasing *time shown by chronometer by* 24^h *if necessary, and putting the day one back.*

2°. *Multiply the rate of chronometer by the number of days elapsed since the original error was ascertained, and* add *thereto the proportionate part for the fraction of a day, found by proportion or otherwise;* the result is the accumulated rate in the interval.

3°. *To the result found by* 1°, add *the accumulated rate, if chronometer is* losing; *but* subtract *if* gaining: the result will be mean time at Greenwich at the instant of observation.

EXAMPLES.

Ex. 1. 1865, January 30th, P.M. at ship, time by chronometer $29^d\ 15^h\ 47^m\ 48^s{\cdot}3$, which was $10^m\ 24^s{\cdot}7$ *slow* on Greenwich mean time January 1st, and *losing* $2^s{\cdot}1$ daily; required the Greenwich date by chronometer.

Time by chron.	$29^d\ 15^h\ 47^m\ 48{\cdot}3^s$
Original error	+ 10 24·7
	29 15 58 13·0
Accumulated rate	+ 1 0·1
Greenwich date	29 15 59 13·1

Interval from January 1st to January 29th, $15^h 58^m$, is $28^d 16^h$ nearly.

Daily rate		$2{\cdot}1^s$
		28
		168
		42
h	d	
12	½	$58{\cdot}8^s$
4	⅙	1·0
		·3
		6,0)6,0·1
Acc. rate		1 0·1

Ex. 2. 1865, March 20th, P.M. at ship, an observation was made when the time by chronometer was $20^d\ 0^h\ 7^m\ 55^s$, which was $50^m\ 51^s$ *fast* on Greenwich mean time November 21st, and *losing* $6^s{\cdot}8$ daily.

Time by chron.	20^d	0^h	7^m	55^s
or	19	24	7	55
Original error	—	0	50	51
	19	23	17	4
Accumulated rate	+		13	29
Greenwich date	19	23	30	33

Nov.	30 days	
	21	
	9	
Dec.	31	
Jan.	31	
Feb.	28	
Mar.	19	23
Intr.	118	23

Daily rate	$6{\cdot}8^s$
	118
	802·4
Prop. part 23^h	6·5
	6,0)80,8·9
Acc. rate	13 28·9

Ex. 3. 1865, September 8th, P.M. at ship, an observation was made when a chronometer showed $7^d\ 23^h\ 16^m\ 28^s$, which was $57^m\ 47^s$ *slow* on Greenwich mean time June 30th, and *losing* $4^s{\cdot}5$; find the Greenwich date by chronometer.

Time by chron.	7^d	23^h	16^m	28^s
Original error	+		57	47
	8	0	14	15
Accumulated rate	+		5	15
Greenwich date	8	0	19	30

June	30 days	
	30	
	0	
July	31	
Aug.	31	
Sept.	8	0
Intr.	70	0

Daily rate	$4{\cdot}5^s$
	70
	6,0)31,5·0
Acc. rate	5 15·0

Ex. 4. 1865, June 28th, A.M. at ship, an observation was made when a chronometer showed $28^d\ 8^h\ 5^m\ 40^s$, which was $15^m\ 22^s$ *fast* on Greenwich mean time May 4th, and *losing* $5^s{\cdot}8$ daily.

Time by chron.	28^d	8^h	5^m	40^s
Original error	—		15	22
	28	7	50	18
Accumulated rate	+		5	21
Greenwich date	28	7	55	39

Interval from May 4th to June $28^d\ 8^h$, is $55\frac{1}{3}$ days; then daily rate $5^s{\cdot}8 \times 55\frac{1}{3} = 320^s{\cdot}9$, or $5^m\ 20^s{\cdot}9$.

Ex. 5. 1865, February 28th, A.M. at ship, an observation was made when chronometer showed $28^d\ 1^h\ 12^m\ 40^s$, which was *fast* $9^m\ 55^s$ on Greenwich mean time January 27th, and *gaining* $3^s{\cdot}9$ daily.

Time by chron.	28^d	1^h	12^m	40^s
Original error	—		9	55
	28	1	2	45
Accumulated rate	—		2	5
Greenwich date	28	1	0	40

Jan.	31	days
	27	
	4	
Feb.	28	
Intr.	32	days

Daily rate	$3{\cdot}9^s$
	32
	124·8
Prop. part. 1^h	0·2
	6,0)12,5·0
Acc. rate	2 5·0

EXAMPLES FOR PRACTICE.

Ex. 1. 1865, February 16th, A.M. at ship, an observation was taken when the corresponding time by a chronometer was $16^d\ 8^h\ 59^m\ 25^s$, which was $1^h\ 14^m\ 23^s$ *fast* on Greenwich mean time January 3rd, and *losing* $10^s.9$ daily.

Ex. 2. 1865, April 19th, P.M. at ship, an observation was taken when a chronometer showed $19^d\ 5^h\ 0^m\ 0^s$, which was *fast* $33^m\ 30^s$ on Greenwich mean time March 19th, and *losing* 5^s daily.

Ex. 3. 1865, May 7th, A.M. at ship, an observation was taken when a chronometer showed $7^d\ 6^h\ 9^m\ 48^s$, which was *fast* $11^m\ 9^s.4$ on Greenwich mean time February 16th, and *losing* $5^s.5$ daily.

Ex. 4. 1865, June 26th, P.M. at ship, an observation was taken when the chronometer showed $25^d\ 21^h\ 29^m\ 53^s$, which was $30^m\ 12^s$ *fast* on Greenwich mean time March 31st, and *gaining* $2^s.2$ daily.

Ex. 5. 1865, October 25th, P.M. at ship, time by chronometer $25^d\ 8^h\ 31^m\ 10^s$, which was $12^m\ 10^s$ *slow* on Greenwich mean time July 20th, and *gaining* $4^s.7$ daily.

Ex. 6. 1865, January 20th, P.M. at ship, time by chronometer $19^d\ 13^h\ 21^m\ 25^s$, which was $53^m\ 47^s$ *fast* on mean time at Greenwich October 31st, 1864, and *losing* 4^s daily.

Ex. 7. Time by chronometer, November $8^d\ 16^h\ 2^m\ 3^s$, which was $33^m\ 0^s$ *slow* on mean time at Greenwich July 31st, and *gaining* $4^s.8$ daily.

Ex. 8. Time by chronometer, August $1^d\ 1^h\ 3^m\ 0^s$, which was $1^h\ 6^m\ 4^s$ *fast* on mean time at Greenwich May 31st, and *losing* $8^s.7$ daily.

Ex. 9. Time by chronometer, May $1^d\ 13^h\ 23^m\ 10^s$, chronometer *slow* $3^m\ 24^s$ on mean time at Greenwich February 2nd, and *losing* $0^s.97$. daily.

TO FIND THE HOUR-ANGLE.

Given the true altitude of an object, its declination, and the latitude of the observer, to find the meridian distance or hour-angle.

RULE LV.

1°. *Find the polar distance by* Rule XLV, page 123.

2°. *Add together the true altitude, latitude, and polar distance; take half their sum, and from the half sum subtract the true altitude, which call the remainder.*

3°. *Add together the secant of latitude, cosecant of polar distance, cosine of half sum, and sine of remainder; the sum of these logs., rejecting* 10 *from the index, will be the log. of sun's hour angle* (Table 31, Norie); *or sine square of sun's hour angle* (Table 69, Raper).

When the polar distance exceeds 90°, take out the secant of reduced declination; or subtract the polar distance from 180°, and take the cosecant of the remainder.

(a) ***When both the latitude and declination are* 0, *take the true altitude from* 90°, *and so get the zenith distance, which convert into time by* Rule XL, *or by* Table 19, Norie, *or* Table 17, Raper; the result is the hour-angle.**

The hour-angle can also be found without a special table, as follows:—Find the sum of the four logs. as above, and divide by 2: the result is the log. sine of *half* the hour-angle in *arc*. From the Table of log. sines find the arc corresponding thereto, which multiplied by 2, and converted into time, (Rule XL, page 114) is the hour-angle sought. It is thus evident that the complete solution may be obtained by means of the Table of log. sines, &c., alone.

Examples.

Ex. 1. Given the true altitude 17° 16′, latitude 50° 42′ S., reduced declination 20° 6′ S. (when polar distance is 69° 54′): find the hour-angle.

Altitude	17° 16′		
Latitude	50 42	sec.	0·198335
Polar dist.	69 54	cosec.	0·027291
Sum	137 52		
Half sum	68 56	cos.	9·555643
Half sum alt.	51 40	sin.	9·894546
Hour-angle	$5^h 48^m 6^s$	log.	9·67581,5
			79
			$1^s = 3$

Ex. 2. Given the true altitude 13° 28′, latitude 10° 35′ S., reduced declination 23° 23′ N. (or polar distance 113° 23′): find the hour-angle.

Altitude	13° 28′		
Latitude	10 35	sec.	0·007451
Polar dist.	113 23	cosec.	0·037219
Sum	137 26		
Half sum	68 43	cos.	9·559883
Half sum alt.	55 15	sin.	9·914685
Hour-angle	$4^h 40^m 46^s$	log.	9·51923,8
			21
			$1^s = 3$

Ex. 3. Given true altitude 15° 10′ 31″, latitude 50° 2′ N., reduced declination, 1° 55′ 43′ S. (or polar distance 91° 55′ 43″): required the hour-angle.

Altitude	15° 10′ 31″		
Latitude	50 2 0	sec.	0·192234
Polar dist.	91 55 43	cosec.	0·000246
Sum	157 8 14		
Half sum	78 34 7	cos.	9·297091
Half sum alt.	63 23 36	sin.	9·951387
Hour-angle	$4^h 13^m 33^s$	log.	9·44095,8
			79
			$3^s = 17$

Ex. 4. Given true altitude 21° 34′ 14″, latitude 38° 18′ S., reduced declination 11° 19′ 52″ S.: find the hour-angle.

Altitude	21° 34′ 14″		
Latitude	38 18 0	sec.	0·105254
Polar dist.	78 40 8	cosec.	0·008468
Sum	138 32 22		
Half sum	69 16 11	cos.	9·548966
Half sum alt.	47 41 57	sin.	9·869009
Hour-angle	$4^h 45^m 26^s$	log.	9·531697

Ex. 5. Latitude 0°, declination 0°, true altitude 30°: required the hour-angle.

True altitude	30° 0′
	90 0
Zenith distance	60 0
	4
	6,0)24,0 0
Hour-angle	$4^h\ 0^m\ 0^s$

Ex. 6. Given true altitude 75°, latitude 0°, declination 0°: find the hour-angle.

True altitude	75° 0′
	90 0
Zenith distance	15 0
	4
	6,0)6,0 0
Hour-angle	$1^h\ 0^m\ 0^s$

Examples for Practice.

Required the hour-angle or meridian distance in each of the following examples:—

1.	True altitude	11° 21′ 29″	Latitude	30° 15′ S.	Declination	15° 21′ 4″ N.
2.	"	30 2 4	"	39 27 S.	"	5 48 23 N.
3.	"	27 48 22	"	40 10 N.	"	23 26 44 N.
4.	"	34 49 46	"	39 20 S.	"	21 15 7 S.
5.	"	13 31 24	"	31 32 S.	"	21 11 47 N.
6.	"	25 38 11	"	0 29 N.	"	23 1 55 N.
7.	"	15 59 13	"	60 5 N.	"	7 25 38 S.
8.	"	29 2 27	"	0 0	"	0 0 0
9.	"	20 34 4	"	0 0	"	23 27 21 N.
10.	"	37 40 0	"	0 0	"	0 0 0

LONGITUDE BY CHRONOMETER.

RULE LVI.

1°. *To the time by chronometer apply its original error and accumulated rate, as directed in* Rule LIV; the result is the Greenwich date at the instant of observation.

2°. *Take out of* Nautical Almanac, page II, *the sun's declination and the equation of time for the noon of Greenwich date and that following it; also take out the sun's semi-diameter.*

3°. *Reduce the sun's declination and equation of time to the Greenwich time* (Rules XLIII and XLVI); *also find the polar distance* (Rule XLV).

4°. *Correct observed altitude for index error, dip, correction in altitude, and semi-diameter, and thus get the true altitude.*

5°. *Find the hour-angle by* Rule LV.

6°. *When the observation is made in the afternoon, the hour-angle is* apparent time past noon of the given day at ship; *but if the observation*

is made in the morning, take the hour-angle from 24^h, *the remainder is* apparent time past noon of the day before that at ship.

7°. *To apparent time apply the reduced equation of time, and so get mean time.*

8°. *Under ship mean time put Greenwich mean time, and take their difference; the remainder is longitude in time, which convert into arc* (Table 17, Raper; *or* Table 19, Norie).

9°. *Call the longitude* West, *when Greenwich time is* greater *than ship mean time; but* East, *when Greenwich mean time is* least.

In taking the difference of Greenwich mean time and ship mean time, if the days of the month be different, put the more advanced one day back, and add 24 to the hours.

Examples.

Ex. 1. 1865, January 11th, P.M. at ship, latitude 49° 30′ N., the observed altitude sun's L.L. was 12° 20′ 30″, height of eye 18 feet, time by a chronometer $11^d\ 8^h\ 24^m\ 36^s$, (being P.M. at Greenwich) which was $1^h\ 48^m\ 42^s$ *fast* for mean noon at Greenwich, September 30th, 1864, and *gaining* $5^s{\cdot}3$ daily; required the longitude by chronometer.

Time by chron.		$11^d\ 8^h 24^m 36^s$
Original error	—	1 48 42
		11 6 35 54
Accumulated rate	—	9 7
Greenwich date		11 6 26 47

Oct.	31 days.	
Nov.	30	
Dec.	31	
Jan.	11	6½
Int.	103	6½

Daily rate			$5^s{\cdot}3$
Interval			103
$103^d\ 6\tfrac{1}{2}^h$			
			159
			530
6	¼		545·9
½	$\tfrac{1}{12}$		1·3
			·1
			6,0)54,7·3
Acc. rate			9 7·3

Decl. page II, N.A.	
11th,	21° 45′ 27″ S.
12th,	21 35 42 S.
log. 3912	9 45.
log. 5706	$6^h 27^m$
log. 9618	— 2 37
11th,	21 45 27 S.
Red. decl.	21 42 50 S.
	90 0 0
Polar dist.	111 42 50

Eq. time, page II, N.A.	
11th, *add*	$8^m 20{\cdot}5^s$
12th, *add*	8 43·6
	23·1
log. 0166	23′ 6″
log. 5706	$6^h 27^m$
log. 5872	6′ 12″
	6·2
	8 20·5
Red. eq. time	8 26·7

(To be *added* to A. T.)

Obs. alt ☉'s L.L.		12° 20′ 30″
Dip,	—	4 4
		12 16 26
Corr. altitude	—	4 9
		12 12 17
Semi-diameter	+	16 18
True altitude		12 28 35

By Raper's Tables: dip — 4′ 10″, ref. — 4′ 23″, par. + 9″, semid. + 16′ 18″, and True altitude 12° 28′ 24″.

Norie.

Altitude	12° 28′ 35″		
Latitude	49 30 0	sec.	0·187456
Polar dist.	111 42 50	cosec.	0·031964
	173 41 25		
	86 50 42	cos.	8·740656
	74 22 7	sine	9·983633
		log.	8·943709
A. T. ship	$11^d\ 2^h 17^m 56^s$		
Eq. time	+ 8 27		
M. T. ship	11 2 26 23		
M. T. Grn.	11 6 26 47		
Long. in time	4 0 24		
Longitude	60° 6′ 0″ W.		

Raper.

Altitude	12° 28′ 24″		
Latitude	49 30 0	sec.	0·187456
Polar dist.	111 42 50	cosec.	0·031964
	173 41 14		
	86 50 37	cos.	8·740838
	74 22 13	sine	9·983637
		sin.sq.	8·943895
A. T. ship	$11^d\ 2^h 17^m 57^s$		
Eq. time	+ 8 27		
M. T. ship	11 2 26 24		
M. T. Grn.	11 6 26 47		
Long. in time	4 0 23		
Longitude	60° 5′ 45″ W.		

Ex. 2. 1865, July 3rd, A.M. at ship, latitude 32° 10′ S., observed altitude sun's L.L. 14° 10′ 15″, index correction + 1′ 22″, height of eye 19 feet, time by a chronometer $2^d\ 16^h\ 33^m\ 22^s$ (being $3^d\ 4^h\ 33^m\ 22^s$ A.M. at Greenwich), which was $16^m\ 22^s$ *fast* for Greenwich mean noon June 1st, and *losing* $3^s{\cdot}4$ daily: required the longitude.

Time by chron.	$2^d\ 16^h 33^m 22^s$
Original error	— 16 22
	2 16 17 0
Accumulated rate	+ 1 48
Greenwich date	2 16 18 48

Interval from June 1st to July 2nd, 16^h, is $31^d\ 16^h$.

Daily rate		$3^s{\cdot}4$
Interval		31
		34
		102
12	½	105·4
4	⅓	1·7
		·6
		6,0)10,7·7
Acc. rate		1 47·7

Decl. page II, N.A.	
2nd,	23° 2′ 8″ N.
3rd,	22 57 24 N.
log. 7050	4 44
log. 1676	$16^h 19^m$
log. 8726	— 3 13
	23 2 8 N.
Red. decl.	22 58 55
	90 0 0
Polar dist.	112 58 55

Eq. time page II, N.A.	
2nd, *add*	$3^m 42{\cdot}7^s$
3rd, *add*	3 53·8
	11·1
log. 3349	11′ 6″
log. 1676	$16^h 19^m$
log. 5025	7 33
	7·5
	3 42·7
Red. eq. time	3 50·2

(To be *added* to app. time.)

Obs. alt. ☉'s L.L.	14° 10′ 15″
Index correction	+ 1 22
	14 11 37
Dip	— 4 11
	14 7 26
Corr. altitude	— 3 35
	14 3 51
Semi-diameter	+ 15 46
True altitude	14 19 37

By Raper: Index corr. + 1′ 22″, dip — 4′ 15″, refr. — 3′ 48″, par. + 8″, semid. + 15′ 46″, True alt, 14° 19′ 28″.

Norie.				*Raper.*			
Altitude	14° 19′ 37″			Altitude	14° 19′ 28″		
Latitude	32 10 0	sec.	0·072371	Latitude	32 10 0	sec.	0·072371
Polar dist.	112 58 55	cosec.	0·035916	Polar dist.	112 58 55	cosec.	0·035916
	159 28 32				159 28 23		
	79 44 16	cos.	9·250794		79 44 11	cos.	9·250854
	65 24 39	sin.	9·958714		65 24 43	sin.	9·958718
Hour-angle	$3^h 37^m 0^s$	log.	9·317795	Hour-angle	$3^h 37^m 1^s$	sin.sq.	9·317859
	24				24		
A. T. ship	2^d 20 23 0			A. T. ship	2^d 20 22 59		
Eq. time	+ 3 50			Eq. time	+ 3 50		
M. T. ship	2 20 26 50			M. T. ship	2 20 26 49		
M. T. Grn.	2 16 18 48			M. T. Grn.	2 16 18 48		
Long. in time	4 8 2			Long. in time	4 8 1		
Longitude	62° 0′ 30″ E.			Longitude	62° 0′ 15″ E.		

Ex. 3. 1865, April 14th, A.M. at ship, latitude 52° 10′ N., observed altitude sun's L.L. 18° 20′ 25″, index correction + 55″, height of eye 12 feet, time by chronometer $14^d\ 5^h\ 5^m\ 5^s$ (being P.M. at Greenwich), which was *fast* $6^m\ 38^s$ for mean noon at Greenwich, February 26th, and *gaining* $3^s{\cdot}8$ daily.

Time by chron.	$14^d\ 5^h\ 5^m\ 5^s$	
Original error	— 6 38	
	14 4 58 27	
Accumulated rate	— 2 59	
Greenwich date	14 4 55 28	

Interval from February 27th, to April 15th 5^h is $47^d\ 5^h$.

Daily rate			$3^s{\cdot}8$
Interval			47
	4	$\frac{1}{6}$	178·6
	1	$\frac{1}{4}$	·6
			·1
			6,0)17,9·3
Acc. rate			2 59·3

Decl. page II, N.A.	
14th,	9° 30′ 56″ N.
15th,	9 52 24 N.
log. 0484	21 28
log. 6885	$4^h 55^m$
log. 7369	+ 4 24
14th,	9 30 56 N.
Red. decl.	9 35 20 N.
	90 0 0
Polar dist.	80 24 40 N.

Eq. time page II, N.A.	
14th, *add*	$0^m 13{\cdot}5^s$
15th, *sub.*	0 1·6
	15·1
log. 2012	15′ 6″
log. 6885	$4^h 55^m$
log. 8897	3′ 6″
	3·1
add	0 13·5
Red. eq. time	0 10·4

(To be *added* to app. time.)

Obs. alt. ☉'s L.L.	18° 20′ 25″
Index correction	+ 55
	18 21 20
Dip	— 3 19
	18 18 1
Corr. altitude	— 2 42
	18 15 19
Semi-diameter	+ 15 58
True altitude	18 31 17

By Raper: Index corr. + 55″, dip, — 3′ 20″, ref. — 2′ 54″, par. + 8″, semid. + 15′ 58″, True altitude 18° 31′ 12″.

Norie.

Altitude	18° 31′ 17″		
Latitude	52 10 0	sec.	0·212280
Polar dist.	80 24 40	cosec.	0·006111
	151 5 57		
	75 32 58	cos.	9·397148
	57 1 41	sin.	9·923729
Hour-angle	4h 48m 19s	log.	9·539268
	24		
A. T. ship	13d 19 11 41		
Eq. time	+ 10		
M. T. ship	13 19 11 51		
M. T. Grn.	13 28 55 28		
Long. in time	9 43 37		
Longitude	145° 54′ 15″ W.		

In this example it is A.M. at ship, *civil time*, April 14th, consequently April 13th, *astronomically*, but at Green. it is P.M., hence it is necessary to add 24 hours to the *latter* in order to reckon both dates from the *same noon*.

Raper.

Altitude	18° 31′ 12″		
Latitude	52 10 0	sec.	0·212280
Polar dist.	80 24 40	cosec.	0·006110
	151 5 52		
	75 32 56	cos.	9·397164
	57 1 44	sin.	9·923733
Hour-angle	4h 48m 20s	sin.sq.	9·539287
	24		
A. T. ship	13d 19 11 40		
Eq. time	+ 10		
M. T. ship	13 19 11 50		
M. T. Grn.	13 28 55 28		
Long. in time	9 43 38		
Longitude	145° 54′ 30″ W.		

Ex. 4. 1865, March 6th, P.M. at ship, latitude 40° 20′ S., observed altitude sun's L.L. 16° 20′, index correction + 30″, height of eye 18 feet, time by a chronometer 5d 20h 30m, (being 6d 8h 30m A.M. at Greenwich), which was 24m 29s *fast* for mean noon at Greenwich February 13th, and *losing* 7s·5 daily.

Time by chron.	5d 20h 30m 0s
Original error	— 24 29
	5 20 5 31
Accumulated rate	+ 2 36
Greenwich date	5 20 8 7

Feb. 28 days.
13
15
Mar. 5 20h
Int. 20 20

Daily rate		7s·5
Interval		20
12	½	150·0
8	⅓	3·7
		2·5
		6,0)15,6·2
		2 36·2

Decl. page II, N.A.	
5th,	5° 55′ 26″ S.
6th,	5 32 12 S.
log. 0141	23 14
log. 0763	20h 8m
log. 0904	— 19 29
	5 55 26 S.
Red. decl.	5 35 57 S.
	90 0 0
Polar dist.	84 24 3 S.

Eq. time page II, N.A.	
5th, *add*	11m 40·5s
6th, *add*	11 26·4
	14·1
log. 2310	14′ 6″
log. 0763	20h 8m
log. 3073	11 50
	— 11·8
5th, noon	11 40·5
Red. eq. time	11 28·7

(To be *added* to app. time.)

Obs. alt. ☉'s L.L.	16° 20′ 0″
Index correction	+ 30
	16 20 30
Dip	— 4 4
	16 16 26
Corr. altitude	— 3 5
	16 13 21
Semi-diameter	+ 16 9
True altitude	16 29 30

By Raper: Index corr. + 30″, dip — 4′ 10″, ref. — 3′ 18″, par. + 8″, semid. + 16′ 9″, True altitude 16° 29′ 19″.

Norie.

Altitude	16° 29′ 30″		
Latitude	40 20 0	sec.	0·117879
Polar dist.	84 24 3	cosec.	0·002077
	141 13 33		
	70 36 46	cos.	9·521073
	54 7 16	sin.	9·908623
A. T. ship	6^d $4^h 52^m 20^s$	log.	9·549652
Eq. time	+ 11 29		
M. T. ship	6 5 3 49	In this example 24 hours is added to the ship time, it being *one day* in advance of Greenwich date.	
or	5 29 3 49		
M. T. Grn.	5 20 8 7		
Long. in time	8 55 42		
Longitude	133° 55′ 30″ E.		

Raper.

Altitude	16° 29′ 19″		
Latitude	40 20 0	sec.	0·117879
Polar dist.	84 24 3	cosec.	0·002077
	141 13 22		
	70 36 41	cos.	9·521103
	54 7 22	sin.	9·908633
M. T. ship	6^d $4^h 52^m 21^s$	sin.sq.	9·549692
Eq. time	+ 11 29		
M. T. ship	6 5 3 50		
or	5 29 3 50		
M. T. Grn.	5 20 8 7		
Long. in time	8 55 43		
Longitude	133° 55′ 45′ E.		

Ex. 5. 1865, November 19th, A.M. at ship, latitude 39° 20′ S., observed altitude sun's L.L. 34° 37′ 55″, index correction + 1′ 10″, height of eye 14 feet, time by chronometer 18^d 23^h 49^m 32^s (or 19^d 11^h 49^m 32^s A.M.), which was *slow* 58^m $52^s·3$ for mean noon at Greenwich, September 19th, and *losing* $6^s·4$ daily.

Time by chron.	$18^d 23^h 49^m 32^s$
Original error	+ 58 52·3
	18 24 48 24·3
or	19 0 48 24·3
Accumulated rate	+ 6 30·6
Greenwich date	19 0 54 54·9

Sept.	30 days.
	19
Sept.	11
Oct.	31
Nov.	19 1^hnrly.
Intr.	61 1^h

Daily rate	$6^s·4$
Interval	61
	390·4
Prop. part. 1^h	0·2
	6,0)39,0·6
Acc. rate	6 30·6

Decl. page II, N.A.

19th,	19° 33′ 0″ S.	
20th,	19 46 41 S.	
log. 2440	13 41	
log. 1·4180	$0^h 55^m$	
log. 1·6620	+ 0 31	
19th,	19 33 0 S.	
Red. decl.	19 33 31 S.	
	90 0 0	
Polar dist.	70 26 29	

Eq. time page II, N.A.

19th, *sub.*	$14^m 22·8^s$
20th, *sub.*	14 8·4
	14·4
log. 2218	14′ 24″
log. 1·4180	$0^h 55^m$
log. 1·6398	0 33
	0·5
	14 22·8
Red. eq. time	14 22·3

(To be *sub.* from app. time.)

Obs. alt. ⊙'s L.L.	34° 37′ 55″
Index correction	+ 1 10
	34 39 5
14 feet	— 3 36
	34 35 29
Corr. altitude	— 1 15
	34 34 14
Semi-diameter	+ 16 14
True altitude	34 50 28

By Raper: Index corr. + 1′ 10″, dip — 3′ 40″, ref. — 1′ 25″, par. + 7″, semid. + 16′ 14″, True alt. 34° 50′ 21″.

Norie.			
Altitude	34° 50′ 28″		
Latitude	39 20 0	sec.	0·111556
Polar dist.	70 26 29	cosec.	0·025811
	144 36 57		
	72 18 28	cos.	9·482735
	37 28 0	sin.	9·784118
Hour-angle	$4^h\ 1^m 56^s$	log.	9·404220
	24		
A. T. ship	18^d 19 58 4		
Eq. time	— 14 22		
M. T. ship	18 19 43 42		
M. T. Grn.	18 24 54 55		
Long. in time	5 11 13		
Longitude	77° 48′ 15″ W.		

Raper.			
Altitude	34° 50′ 21″		
Latitude	39 20 0	sec.	0·111556
Polar dist.	70 26 29	cosec.	0·025811
	144 36 50		
	72 18 25	cos.	9·482755
	37 28 4	sin.	9·784129
Hour-angle	$4^h\ 1^m 56^s$	log.	9·404251
	24		
A. T. ship	18^d 19 58 4		
Eq. time	— 14 22		
M. T. ship	18 19 43 42		
M. T. Grn.	18 24 54 55		
Long. in time	5 11 13		
Longitude	77° 48′ 15″ W.		

Ex. 6. 1865, June 15th, P.M. at ship, latitude 13° 54′ S., observed altitude sun's L.L. 16° 16′ 16″, index correction + 16″, height of eye 16 feet, time by a chronometer $15^d\ 0^h\ 16^m\ 16^s$ (or $0^h\ 16^m\ 16^s$ P.M.), which was $2^h\ 16^m\ 16^s$ *fast* for mean noon at Greenwich, April 16th, and *gaining* $10^s{\cdot}6$ daily.

Time by chron.	$15^d\ 0^h\ 16^m\ 16^s$
Original error	— 2 16 16
	14 22 0 0
Accumulated rate	— 10 35
Greenwich date	14 21 49 25

April	30 days.
	16
	14
May	31
June	$14\ 22^h$
Int.	$59\ 22^h$

Daily rate		$10^s{\cdot}6$
Interval		59
12	$\frac{1}{2}$	625·4
8	$\frac{1}{3}$	5·3
2	$\frac{1}{4}$	3·5
		·9
		6,0)63,5·1
		10 35·1

Decl. page II, N.A.	
14th,	23° 17′ 18″ N.
15th,	23 19 57 N.
log. 9570	2 39
log. 0414	$21^h 49^m$
log. 9984	+ 2 25
14th,	23 17 18 N.
Red. decl.	23 19 43 N.
Polar dist.	113 19 43 N.

Eq. time page II, N.A.	
14th, *sub.*	$0^m\ 4{\cdot}2^s$
15th, *add*	0 8·4
	12·6
log. 2798	12′ 36″
log. 0414	$21^h 49^m$
log. 3212	11 27
	11·4
14th, *sub.*	0 4·2
Red. Eq. T.	0 7·2

(To be *added* to A.T.)

Obs. alt ☉'s L.L.	16° 16′ 16″
Index correction	+ 16
	16 16 32
16 feet	— 3 50
Corr. altitude	16 12 42
	— 3 5
	16 9 37
Semi-diameter	+ 15 47
True altitude	16 25 24

By Raper: Index corr. + 16″, dip — 4′ 0″, ref. — 3′ 18″ par. + 8″, semid. + 15′ 47″, True altitude 16° 25′ 9″.

Altitude	16° 25′ 24″		
Latitude	13 54 0	sec.	0·012908
Polar dist.	113 19 43	cosec.	0·037040
	143 39 7		
	71 49 33	cos.	9·494024
	55 24 9	sin.	9·915485
A.T. ship	15ᵈ 4ʰ 19ᵐ 40ˢ	log.	4·459457

Apparent time at ship	15ᵈ 4ʰ 19ᵐ 40ˢ
Equation time	+ 7
Mean time at ship	15 4 19 47
or	14 28 19 47
Mean time Greenwich	14 21 49 25
Longitude in time	6 30 22
Longitude	97° 35′ 30″ E.

Ex. 7. 1865, September 23rd, A.M. at ship, latitude 59° 30′ N., observed altitude sun's L.L. 10° 50′ 10″, index correction + 6′ 10″, height of eye 18 feet, time by chronometer 22ᵈ 11ʰ 44ᵐ 20ˢ (or 22ᵈ 11ʰ 44ᵐ 20ˢ P.M.), which was 30ᵐ 4ˢ *fast* for mean noon at Greenwich, August 13th, and *losing* 10ˢ·5 daily.

Time by chron.	22ᵈ 11ʰ 44ᵐ 20ˢ
Original error	— 30 4
	22 11 14 16
Accumulated rate	+ 7 5
Greenwich date	22 11 21 21

Interval 40ᵈ 11ʰ

Daily rate		10ˢ·5
Interval		40
8	⅓	420·0
3	⅛	3·5
		1·3
		6,0)42,4·8
Acc. rate		7 4·8

Decl. page II, N.A.	
22nd,	0° 12′ 40″ N.
23rd,	0 10 45 S.
log. 0107	23 25
log. 3252	11ʰ 21ᵐ
log. 3359	11 4 S.
	0 12 40 N.
Red. decl.	0 1 36 N.
	90 0 0
Polar dist.	89 58 24

Eq. time page II, N.A.	
22nd, *sub.*	7ᵐ 23ˢ·0
23rd, *sub.*	7 43·8
	20·8
log. 0621	20′ 48′
log. 3252	11ʰ 21ᵐ
log. 3873	9 50
	9·8
	7 23·0
Red. Eq. T.	7 32·8
(*Subt.* from A.T.)	

Obs. alt. ☉'s L.L.	10° 50′ 10″
Index correction	+ 6 10
	10 56 20
Dip	— 4 4
	10 52 16
Corr. altitude	— 4 42
	10 47 34
Semi-diameter	+ 15 59
True altitude	11 3 33

By Raper: Index corr. + 6′ 10″, dip — 4′ 10″, ref. — 4′ 55″, par. + 8″, semid. + 15′ 59″, True alt. 11° 3′ 22″.

Altitude	11° 3′ 33″		
Latitude	59 30 0	sec.	0·294531
Polar dist.	89 58 24	cosec.	0·000000
	160 31 57		
	80 15 58	cos.	9·228073
	69 12 25	sin.	9·970751
Hour-angle	4ʰ 31ᵐ 22ˢ	log.	9·493355

Hour-angle	4ʰ 31ᵐ 22ˢ
	24
Apparent time at ship	22ᵈ 19 28 38
Equation time	— 7 33
Mean time at ship	22 19 21 5
Mean time Greenwich	22 11 21 21
Longitude in time	7 59 44
Longitude	119° 56′ 0 E.

Examples for Practice.

Ex. 1. 1865, January 2nd, A.M. at ship, latitude 36° 59′ S., observed altitude sun's L.L. 49° 10′, index correction — 2′ 40″, height of eye 14 feet, time by a chronometer $1^d\ 19^h\ 8^m\ 50^s$ (being $7^h\ 8^m\ 50^s$ A.M. at Greenwich), which was *slow* $18^m.2^s$ for mean noon at Greenwich, November 30th, 1864, and *losing* $6^s.8$ daily.

Ex. 2. 1865, February 19th, P.M. at ship, latitude 38° 18′ S., observed altitude sun's L.L. 21° 30′ 40″, index correction — 6′ 45″, height of eye 14 feet, time by a chronometer $18^d\ 19^h\ 53^m\ 37^s.6$ (being $7^h\ 53^m\ 37^s.6$ A.M. at Greenwich), which was $4^m\ 16^s.6$ *fast* for mean noon at Greenwich, January 23rd, and *gaining* $7^s.6$ daily.

Ex. 3. 1865, March 28th, P.M. at ship, latitude 20° 19′ S., observed altitude sun's L.L. 30° 14′, index correction — 2′ 10″, height of eye 30 feet, time by chronometer $28^d\ 0^h\ 10^m$ (being $0^h\ 10^m$ P.M. at Greenwich), which was $51^m\ 56^s$ *fast* for mean noon at Greenwich, December 2nd, 1864, and *losing* $4^s.0$ daily.

Ex. 4. 1865, April 6th, A.M. at ship, latitude 53° 5′ N., observed altitude sun's L.L. 16° 8′ 40″, index correction — 40″, height of eye 15 feet, time by a chronometer $5^d\ 19^h\ 18^m\ 49^s$ (being $7^h\ 18^m\ 49^s$ A.M. at Greenwich), which was $2^m\ 38^s$ *fast* for mean noon at Greenwich, March 11th, and *gaining* $5^s.6$ daily.

Ex. 5. 1865, May 1st, P.M. at ship, latitude 21° 8′ N., observed altitude sun's L.L. 28° 5′ 30″, index correction + 2′ 50″, height of eye 16 feet, time by a chronometer, April $30^d\ 18^h\ 50^m\ 29^s.4$ (being $6^h\ 50^m\ 29^s.4$ A.M. at Greenwich), which was $10^m\ 12^s$ *slow* for mean noon at Greenwich, December 31st, 1864, and *gaining* $3^s.3$ daily.

Ex. 6. 1865, June 15th, A.M. at ship, latitude 12° 11′ N., observed altitude sun's L.L. 39° 39′ 40″, index correction + 20″, height of eye 17 feet, time by a chronometer $14^d\ 17^h\ 59^m\ 30^s$ (being $5^h\ 59^m\ 30^s$ A.M. at Greenwich), which was $2^m\ 29^s.5$ *slow* for mean noon at Greenwich, May 12th, and *gaining* $9^s.4$ daily.

Ex. 7. 1865, July 5th, A.M. at ship, latitude 23° 48′ N., observed altitude sun's L.L. 48° 36′ 50″, index correction — 50″, height of eye 17 feet, time by a chronometer $5^d\ 0^h\ 42^m\ 38^s$ (being $0^h\ 42^m\ 38^s$ P.M. at Greenwich), which was $6^m\ 50^s$ *fast* for mean noon at Greenwich, June 1st, and *gaining* $4^s.7$ daily.

Ex. 8. 1865, August 13th, A.M. at ship, latitude 30° 46′ S., observed altitude sun's L.L. 27° 15′, index correction — 1′ 15″, height of eye 21 feet, time by chronometer $13^d\ 2^h\ 0^m$ (being $2^h\ 0^m$ P.M. at Greenwich), which was $25^m\ 13^s$ *slow* for mean noon at Greenwich, May 1st, and *gaining* $2^s.6$ daily.

Ex. 9. 1865, September 1st, P.M. at ship, latitude 35° 49′ N., observed altitude sun's L.L. 44° 32′ 10″, index correction + 1′ 46″, height of eye 20 feet, time by chronometer, August $31^d\ 19^h\ 24^m\ 57^s$ (being $7^h\ 24^m\ 57^s$ A.M. at Greenwich), which was $12^m\ 17^s$ *fast* for mean noon at Greenwich, July 31st, and *gaining* $0^s.7$ daily.

Ex. 10. 1865, October 25th, P.M. at ship, latitude 51° 30′ S., observed altitude sun's L.L. 40° 22′, index correction — 1′ 50″, eye 20 feet, time by a chronometer $25^d\ 8^h\ 22^m\ 1^s$ (or $8^h\ 22^m\ 1^s$ P.M.) *slow* $21^m\ 19^s$ on July 20th, and *gaining* $4^s.7$ daily.

Ex. 11. 1865, November 27th, A.M. at ship, latitude 39° 20′ S., observed altitude sun's L.L. 34° 37′ 55″, index correction + 1′ 15″, eye 18 feet, time by a chronometer $27^d\ 7^h\ 41^m\ 30^s$ (being P.M. at Greenwich), *fast* $29^m\ 40^s$ on November 9th, and *losing* $6^s{\cdot}7$ daily.

Ex. 12. 1865, December 25th, A.M. at ship, latitude 9° 59′ S., observed altitude sun's L.L. 10° 38′ 45″, index correction — 3′ 12″, eye 18 feet, time by a chronometer $24^d\ 15^h\ 29^m\ 50^s$ (being A.M. at Greenwich), *slow* $38^m 59^s{\cdot}5$ July 29th, and *losing* $9^s{\cdot}3$ daily.

Ex. 13. 1865, January 1st, P.M. at ship, latitude 38° 28′ S., observed altitude sun's L.L. 39° 0′, index correction, — 2′ 25″, eye 12 feet, time by a chronometer $1^d\ 11^h\ 58^m\ 29^s$ (being P.M. at Greenwich), *slow* $1^h\ 52^m\ 53^s$ on October 13th, 1864, and *losing* $6^s{\cdot}9$ daily.

Ex. 14. 1865, February 11th, A.M. at ship, latitude 53° 12′ N., observed altitude sun's L.L. 12° 10′, index correction — 49″, eye 12 feet, time by a chronometer $10^d\ 22^h\ 22^m\ 22^s$ (being A.M. at Greenwich), *fast* $38^m\ 59^s$ on December 1st, 1864, and *gaining* $8^s{\cdot}3$ daily.

Ex. 15. 1865, October 26th, A.M. at ship, latitude 28° 10′ N., observed altitude sun's U.L. 25° 32′ 20″, index correction 0′, eye 17 feet, time by chronometer $0^h\ 54^m\ 6^s$ (being P.M. at Greenwich), *fast* on September 4th, $30^m\ 6^s$, *losing* $2^s{\cdot}5$ daily.

Ex. 16. 1865, February 6th, P.M. at ship, latitude 6° 58′ N., observed altitude sun's U.L. 21° 43′ 40″, index correction 0′, eye 18 feet, time by chronometer $11^h\ 40^m\ 26^s$ (being A.M at Greenwich), *slow* $17^m\ 42^s$ on January 20th, and *losing* $5^s{\cdot}4$ daily.

Ex. 17. 1865, April 21st, P.M. at ship, latitude at noon 0° 19′ N., observed altitude sun's U.L. 32° 21′ 10″, index correction — 1′ 10″, eye 12 feet, time by a chronometer $3^h\ 44^m\ 1^s$ (being A.M. at Greenwich), *slow* $9^m\ 7^s$ on November 14th, 1864, *gaining* $1^s{\cdot}6$ daily, course since noon S.W. by W. (true), distance 56 miles: required longitude at time of observation and also at noon.

Ex. 18. 1865, August 21st, A.M. at ship, latitude at noon, 0° 20′ S., observed altitude sun's L.L. 33° 49′, index correction + 2′ 10″, eye 15 feet, time by chronometer $8^h\ 14^m\ 0^s$ (being P.M. at Greenwich), *slow* $4^m\ 40^s$ on March 13th, *losing* $1^s{\cdot}25$ daily, course S.W. by W., 36 miles.

Ex. 19. 1865, March 20th, A.M. at ship, latitude 0°, observed altitude sun's L.L. 28° 50′ 10″, index correction + 1′, eye 23 feet, time by chronometer $20^d\ 2^h\ 0^m$ (being P.M. at Greenwich), which was *fast* $2^m\ 8^s$ on Greenwich mean noon, February 28th, and *gaining* $0^s{\cdot}3$ daily.

Ex. 20. 1865, June 15th, A.M. at ship, latitude 29° 10′ S., observed altitude sun's L.L. 30° 40′, eye 25 feet, time by chronometer $14^d\ 10^h\ 59^m\ 20^s$ (being P.M. on 14th at Greenwich), *fast* $4^m\ 35^s$ on Greenwich mean noon, March 20th, *losing* 8^s daily.

Ex. 21. 1865, March 21st, A.M. at ship, latitude 41° 32′ S., observed altitude sun's L.L. 32° 59′, eye 20 feet, time by chronometer $21^d\ 3^h\ 28^m$ (being P.M. at Greenwich), *fast* $1^m\ 40^s$ on mean time at Greenwich, December 20th, 1864, *losing* $0^s{\cdot}9$ daily.

VARIATION BY AN AZIMUTH.

Given the latitude, altitude, and declination of an object, to find the true azimuth.

RULE LVII.

1°. *Add together the polar distance, the latitude, and the altitude, take half the sum, and take the difference between the half sum and the polar distance.*

2°. *Add together the log. secant of latitude, the log. secant of altitude, the log. cosines of the half sum and remainder; the sum (rejecting tens) is log. sine square of true azimuth* (Table 69, Raper). *Or, half the sum of the four logs. is the log. sine of half the true azimuth, which take out of the table* (Table 24, Norie), *and double it: the result is the true azimuth.*

3°. *Mark the true azimuth* N. *when the latitude is* S., *but mark it* S., *when the latitude is* N.; *also, mark it* E. *when it is* A.M., *or the altitude is* increasing, *but* W. *when it is* P.M., *or the altitude is* decreasing.

(a) *When* latitude *is* 0, *if* declination *is* N., *reckon the azimuth from the* South; *if* declination *is* S., *reckon the azimuth from the* North.

(b) *When* both latitude *and* declination *are* 0, *the object moves on the prime vertical, or is* E. *while the altitude is* increasing, *and* W. *while the altitude is* decreasing.

EXAMPLES.

Ex. 1. Given the latitude 47° 46′ S.; declination 22° 27′ 22″ (or polar distance 67° 32′ 38″); true altitude 26° 44′. (being P.M.)

Norie.

Polar dist.	67° 32′ 38″		
Latitude	47 46 0	sec.	0·172533
Altitude	26 44 0	sec.	0·049095
Sum	142 2 38		
½ sum	71 1 19	cos.	9·512159
½ sum p. dist.	3 28 41	cos.	9·999200
			2)19·732987
	47° 20′ 12″	sine	9·866493
	2		470
True az. N.	94 40 24 W.		2300
		12″ =	194

Raper.

Polar dist.	67° 32′ 38″		
Latitude	47 46 0	sec.	0·172533
Altitude	26 44 0	sec.	0·049095
Sum	142 2 38		
½ sum	71 1 19	cos.	9·512159
½ sum p. dist.	3 28 41	cos.	9·999200
True az. N. 94° 40′ 24″ W.		sin.sq.	9·732987
			969
			9 = 18

The true azimuth is here marked N. because the latitude is S., and W. because the altitude is *decreasing*, it being P.M.

Ex. 2. Latitude 25° 32′ N., declination 17° 37′ 46″ S., true altitude 15° 44′ 53″.

Polar dist.	107° 37′ 46″	
Latitude	25 32 0	sec. 0·016615
Altitude	15 44 53	sec. 0·044632
	148 54 39	
	74 27 19	cos. 9·428119
	33 10 27	cos. 9·922731
		2)19·412097
	30 32 42	sine 9·706048
	2	
True az.	S. 61 5 24 W.	

Ex. 3. Latitude 28° 3′ N., declination 12° 39′ 31″ S., true altitude 25° 11′ 49″.

Polar dist.	102° 39′ 31″	
Latitude	28 3 0	sec. 0·054267
Altitude	25 11 49	sec. 0·043424
	155 54 20	
	77 57 10	cos. 9·319559
	24 42 21	cos. 9·958309
		2)19·375559
	29 9 43	sine 9·687779
	2	
True az.	S. 58 19 26 E.	

Ex. 4. Latitude 38° 46′ N. declination 7° 41′ 56″, true altitude 27° 16′ 8″.

Polar dist.	97° 41′ 56″	
Latitude	38 46 0	sec. 0·108071
Altitude	27 16 8	sec. 0·051164
Sum	163 44 4	
½ sum	81 52 2	cos. 9·150657
Remainder	15 49 54	cos. 9·983206
		2)19·293098
	26 18 18	sine 9·646549
	2	
True az.	S. 52 36 36 W.	

Ex. 5. Latitude 34° 19′ S., declination 7° 4′ 27″ S., true altitude 40° 55′ 57″.

Polar dist.	82° 55′ 33″	
Latitude	34 19 0	sec. 0·083054
Altitude	40 55 57	sec. 0·121776
Sum	158 10 30	
½ sum	79 5 15	cos. 9·277173
Remainder	3 50 18	cos. 9·999025
		2)19·481028
	33 22 48	sine 9·740514
	2	
True az.	N. 66 45 36 E.	

Examples for Practice.

In each of the following examples it is required to find the true azimuth:—

1.	True altitude 7° 43′ 27″	+	Declination 11° 28′ 32″ N.	Latitude 51° 10′ N.
2.	„ 28 30 53	+	„ 21 56 45 S.	„ 26 20 N.
3.	„ 43 55 7	—	„ 18 37 14 S.	„ 45 31 S.
4.	„ 12 50 46	—	„ 9 36 51 S.	„ 15 47 N.
5.	„ 29 41 59	+	„ 2 38 14 N.	„ 4 22 N.
6.	„ 7 15 55	—	„ 12 14 38 S.	„ 51 2 N.
7.	„ 13 47 28	—	„ 17 50 57 S.	„ 42 36 N.
8.	„ 13 44 0	+	„ 6 40 0 S.	„ 51 30 N.
9.	„ 45 30 0	—	„ 23 2 0 S.	„ 0 0
10.	„ 25 40 10	+	„ 0 0 0	„ 0 0
11.	„ 40 7 21	—	„ 17 4 3 S.	„ 33 51 S.
12.	„ 13 44 0	+	„ 6 40 0 S.	„ 51 30 N.
13.	„ 26 10 1	+	„ 14 52 13 S.	„ 36 2 S.
14.	„ 23 40 13	—	„ 20 27 27 N.	„ 21 44 N.

Given the true bearing and compass bearing, to find the variation.

RULE LVIII.

1°. *Reckon the true and magnetic azimuth from the same point of the compass, and* take their difference *for the variation, except when one azimuth is reckoned towards the* East, *and the other is reckoned towards the* West, *in which case take the sum.*

(a) *If one of the azimuths be expressed from the* North, *and the other from the* South, *take either of them from* 180°, *and it will then be reckoned from the same point as the other* (see examples 7 and 8).

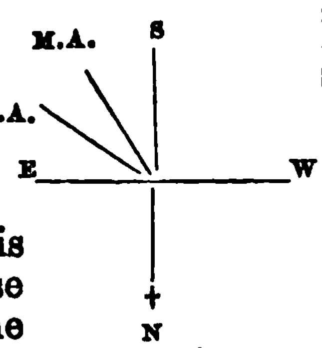
(b) *If the bearing by compass be reckoned from* East *or* West *towards* North *or* South, *take it from* 90°, *and reverse the position of the letters, or* add 90° *and it will then be expressed from the opposite point to that from which it is reckoned when taken from* 90° (see example 5).

(c) *When the magnetic azimuth is either* East *or* West, *it is reckoned as* 90° *from* North *or* South, *according as the true azimuth is* North *or* South.

Examples.

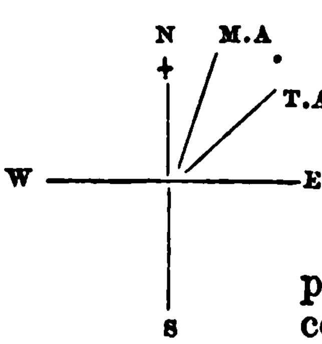
Ex. 1. Given true azimuth S. 70° 57′ E. the magnetic azimuth S.E. by E. ¾ E.; required the variation.

True az.	S. 70° 57′ 0″ E.	
Mag. az.	S. 64 41 15 E.	
Variation	6 15 45 W.	



The variation is in this instance West, because when looking from the centre of the compass in the direction of the magnetic azimuth, the *true azimuth* is on the *left* hand of the magnetic.

Ex. 2. Given true azimuth N. 44° 20′ E., and the sun's bearing by compass (or magnetic azimuth) N. 17° 10′ E.: required the variation.



True az.	N. 44° 20′ E.
Mag. az.	N. 17 10 E.
Variation	27 10 E.

The observer being supposed looking from the centre of the compass in the direction of the magnetic azimuth, then the *true azimuth* lies to the *right* hand of the magnetic azimuth, whence the variation is to be marked *East*.

Ex. 3. True azimuth N. 50° 12′ E., and the magnetic azimuth N. 61° 50′ E.: required the variation.

True azimuth	N. 50° 12′ E.
Magnetic azimuth	N. 61 50 E.
Variation	11 38 W.

The variation is here West, because the *true azimuth* is to the *left* hand of the magnetic azimuth, the observer being supposed to look from the centre of the compass in the direction of the magnetic azimuth.

Ex. 4. The true azimuth S. 62° 41′ E., and magnetic azimuth E.S.E.: required the variation.

	True az.	S. 62° 41′ E.
S. 6 pts. E. =	Mag. az.	S. 67 30 E.
	Variation	4 49 E.

Here the variation is East, since the *true azimuth* is on the *right* of the magnetic azimuth, the observer looking from the centre of the compass in the direction of the magnetic azimuth.

Ex. 5. The true azimuth S. 82° 50′ W. and magnetic azimuth W. 15° N.: required the variation.

	True az. S.	82° 50′ W.
W. 15° N. =	Mag. az. S.	105 0 W.
	Variation	22 10 W.

The variation is West, the *true* azimuth being to the *left* of *magnetic*. 90° is *added* to the compass bearing, in order to reckon it from the same point as the true azimuth: thus from S. to W. is 90°, and from W. to W. 15° N., is 15° more; hence magnetic azimuth is S. 105° W.

Ex. 6. The true azimuth is S. 76° W., and the magnetic azimuth W.: required the variation.

True azimuth	S.	76° 0′ W.
Mag. azimuth	S.	90 0 W.
Variation		14 0 W.

The magnetic azimuth West is reckoned as 90° from S., because the true azimuth is reckoned from S.

Ex. 7. The true azimuth S. 90° 33′ E. and magnetic azimuth N. 81° 20′ E.: find the variation.

True azimuth	S.	90° 33′ E.
		180 0
or,	N.	89 27 E.
Mag. azimuth	N.	81 20 E.
Variation		8 7 E.

The *true* azimuth being reckoned from S. while the magnetic azimuth is expressed from N., the true is subtracted from 180°, in order to reckon it from the same point as the magnetic azimuth, viz., from N.

Ex. 8. The true azimuth N. 69° 39′ W. and magnetic azimuth S. 93° 30′ W.: find the variation.

True azimuth	N.	69° 39′ W.
		180 0
or,	S.	110 21 W.
Mag. azimuth	S.	93 30 W.
Variation		16 51 E.

The *true* azimuth is here taken from 180°, in order to reckon it from the same point as the magnetic azimuth.

RULE LIX.

1°. *With ship time and longitude in time find the Greenwich date* (Rule XLII, page 116).

2°. *Take from* page II, Nautical Almanac, *the sun's declination and reduce it to Greenwich date* (Rule LIV, page 155); *also take out the sun's semi-diameter.*

3°. *Correct observed altitude for index error, dip, refraction, parallax, and semi-diameter, and thus get the true altitude* (Rule XLVIII, page 128).

4°. *Proceed according to* Rule LVII, page 169, *to find the true azimuth.*

5°. *Having found the true azimuth, proceed by* Rule LVIII *to find the variation.*

Examples.

Ex. 1. 1865, May 19th, $3^h\ 7^m\ 44^s$ P.M. mean time at ship, latitude 41° 52′ N., longitude 57° 4′ W., sun's bearing by compass S. 94° 40′ W., the observed altitude sun's L.L. 43° 56′ 22″, eye 18 feet, index correction 0: required the true azimuth and variation.

Ship date, May	19^d	3^h	7^m	44^s
Long. 57° 4′ W.	+	3	48	16
Greenwich date	19	6	56	0

Decl. 19th,	19°	49′	52″	N.
20th,	20	2	28	N.
log. 2798		12	36	
log. 5393		6	56	
log. 8191	+	3	38	
	19	49	52	
Reduced declination	19	53	30	N.
	90	0	0	
Polar distance	70	6	30	

Obs. alt. ☉'s L.L.	43°	56′	22″
Dip (T. 4)	—	4	4
	43	52	18
Corr. altitude (T. 18)	—		53
	43	51	25
Semi-diameter	+	15	50
True altitude	44	7	15

By Raper: Dip — 4′ 10″, ref. — 1′ 1″, parallax + 6″, semid. + 15′ 50″, True altitude 44° 7′ 7″.

Norie.

Polar dist.	70°	6′	30″		
Latitude	41	52	0	sec.	0·128019
Altitude	44	7	15	sec.	0·143922
	156	5	45		31
	78	2	52	cos.	9·316172
	7	56	22	cos.	9·995817
					2)19·583961
	38	16	24	sine	9·791980
			2		
True az.	S. 76	32	48	W.	
Mag. az.	S. 94	40	0	W.	
Variation	18	7	12	W.	

Raper.

Polar dist.	70°	6′	30″		
Latitude	41	52	0	sec.	0·128019
Altitude	44	7	7	sec.	0·143936
	156	5	37		
	78	2	48	cos.	9·316210
	7	56	18	cos.	9·995818
True az.	S. 76	32	56 W.	sin. sq.	9·583983
Mag. az.	S. 94	40	0 W.		
Variation	18	7	4 W.		

The true being to the *left* of magnetic.

Ex. 2. 1865, September 2nd, mean time at ship 8^h 59^m A.M., latitude 39° 30′ S., longitude 127° 45′ W., sun's bearing by compass N. 39° 34′ E., observed altitude sun's L.L. 26° 40′ 35″, height of eye 18 feet: required the true azimuth and variation.

Ship date, Sept.	1^d	20^h	59^m
Long. 127° 45′ W.	+	8	31
Greenwich date	2	5	30

Decl. 2nd,	7°	49′	50″	N.
3rd,	7	27	49	N.
log. 0375		22	1	
log. 6398		5^h	30^m	
log. 6773		5	3	
	7	49	50	N.
Reduced declination	7	44	47	N.
	90	0	0	
Polar distance	97	44	47	N.

Obs. alt. ☉'s L.L.	26°	40′	35″
Dip (T. 4)	—	4	4
	26	36	31
Corr. altitude	—	1	45
	26	34	46
Semi-diameter	+	15	54
True altitude	26	50	40

By Raper: Dip — 4′ 10″, ref. — 1′ 56″, par. + 8″, semid. + 15′ 54″, True altitude 26° 50′ 31″. True azimuth N. 52° 11′ 53″ E., variation 12° 37′ 53″ E.

Polar dist.	97° 44′ 47″		
Latitude	39 30 0	sec.	0·112594
Altitude	26 50 40	sec.	0·049478
	164 5 27		43
	82 2 43	cos.	9·141106
	15 42 4	cos.	9·983485
			2)19·286706
	26 5 51	sine	9·643353

		26° 5′ 51″
		2
True azimuth	N.	52 11 42 E.
Magnetic azimuth	N.	39 34 0 E.
Variation		12 37 42 E.

The true being to the *right* of magnetic.

Ex. 3. 1865, July 5th, mean time at ship $6^h\ 55^m\ 51^s$ P.M., latitude 50° 53′ N., longitude 119° 8′ E., sun's bearing by compass N. 65° 30′ W., observed altitude sun's L.L. 9° 40′, index correction + 3′ 50″, height of eye 18 feet.

Ship date, July	5^d	$6^h 55^m 51^s$
Long. 119° 8′ E.	—	7 56 32
Greenwich date	4	22 59 19
Decl. 4th,		22° 52′ 17″ N.
5th,		22 46 46 N.
log. 6385		5 31
log. 0188		$22^h 59^m$
log. 6573	—	5 17
		22 52 17 N.
Reduced declination		22 47 0 N.
Polar distance		67 13 0

Obs. alt. ☉'s L.L.	9° 40′ 0″
Index correction	+ 3 50
	9 43 50
Dip	— 4 4
	9 39 46
Corr. altitude	— 5 17
	9 34 29
Semi-diameter	+ 15 46
True altitude	9 50 15

By Raper: Index corr. + 3′ 50″, dip — 4′ 10″, ref. — 5′ 31″, par. + 8″, semid. + 15′ 46″, True alt. 9° 50′ 3″. true az. S. 114° 11′ 30″ W., variation 0° 18′ 30″ W.

Polar dist.	67° 13′ 0″		
Latitude	50 53 0	sec.	0·200038
Altitude	9 50 15	sec.	0·006428
	127 56 15		6
	63 58 7	cos.	9·642360
	3 14 53	cos.	9·999302
			2)19·848134
	57 5 49	sine	9·924067

		57° 5′ 49″
		2
True azimuth	S.	114 11 38 W.
		180 0 0
True azimuth	N.	65 48 22 W.
Magnetic azimuth	N.	65 30 0 W.
Variation		0 18 22 W.

The *true* being to the left of *magnetic*.

Ex. 4. 1865, February 10th, at $8^h\ 2^m$ A.M. mean time at ship, latitude 50° 48′ N., longitude 91° 10′ W., sun's bearing by compass S. 70° 10′ E., observed altitude sun's L.L. 7° 10′ 40″, index correction — 1′ 10″, height of eye 15 feet.

Ship date, Feb.	$9^d\,20^h\,2^m\,0^s$	Obs. alt. ⊙'s L.L.	7° 10′ 40″
Long. 91° 10′ W.	6 4 40	Index correction	— 1 10
	9 26 6 40		7 9 30
	24	Dip	— 3 42
Greenwich date	10 2 6 40		7 5 48
		Corr. alt.	— 7 6
Decl. 10th,	14° 14′ 20″ S.		6 58 42
11th,	13 54 39 S.	Semi-diameter	+ 16 14
log. ·0861	19 41		
log. 1·0546	$2^h\,7^m$	True altitude	7 14 56
log. 1·1407	— 1 44		
	14 14 20 S.		
Red. declination	14 12 36		
Polar distance	104 12 36		

By Raper: Index corr. — 1′ 10″ dip — 3′ 50″, ref. — 7′ 19″, par. + 9″, semid. + 16′ 14″, True alt. 7° 14′ 44″, T. az. S. 56° 48′ 38″ E. variation 13° 21′ 22″ E.

Polar dist.	104° 12′ 36″		
Latitude	50 48 0	sec.	0·199263
Altitude	7 14 56	sec.	0·003470
	162 15 32		15
	81 7 46	cos.	9·188092
	23 4 50	cos.	9·963766
			2)19·354606
	28 24 10	sine	9·677303

		28° 24′ 10″	
		2	
True azimuth	S.	56 48 20	E.
Magnetic azimuth	S.	70 10 0	E.
Variation		13 21 40	E.

The *true* azimuth being to the *right* of *magnetic*.

Ex. 5. 1865, January 21st, at $10^h\,14^m$ A.M., mean time at ship, latitude 39° 3′ S., longitude 96° 28′ E., sun's bearing by compass E. 2° 30′ S., observed altitude sun's U.L. 46° 15′, index correction — 2′ 20″, height of eye 19 feet.

Ship date, Jan.	$20^d\,22^h\,14^m\,0^s$	Obs. alt. ⊙'s U.L.	46° 15′ 0″
Long. 96° 28′ E.	— 6 25 52	Index correction	— 2 20
Greenwich date	20 15 48 8		46 12 40
		Dip	— 4 11
Decl. 20th,	20° 3′ 5″ S.		46 8 29
21st,	19 49 46 S.	Corr. altitude	— 49
log. 2558	13 19		46 7 40
log. 1816	$15^h\,48^m$	Semi-diameter	— 16 17
log. 4374	8 46		
	20 3 5 S.	True altitude	45 51 23
Reduced declination	19 54 19 S.		
Polar distance	70 5 41		

By Raper: Index corr. — 2′ 20″, dip — 4′ 15″, ref. — 56″, par. + 6″, semid. — 16′ 17″, True altitude 45° 51′ 18″. True azimuth N. 78° 5′ 33″ E., var. 14° 24′ 27″ W.

Polar dist.	70° 5′ 41″		
Latitude	39 3 0	sec. 0·109805	
Altitude	45 51 23	sec. 0·157054	
	155 0 4	50	
	77 30 2	cos. 9·335318	
	7 24 21	cos. 9·996362	
		2)19·598589	
	39 2 42	sine 9·799294	

		39° 2′ 42″	
		2	
True az.	N.	78 5 24 E.	
Mag. az.	S.	92 30 0 E.	= E. 2° 30′ S.
Variation		14 24 36 W.	

Ex. 6. 1865, June 1st, at 9^h 40^m A.M. mean time at ship, latitude 60° N., longitude 40° 20′ W., observed altitude sun's L.L. 44° 48′ 50″, index correction + 3′ 17″, height of eye 18 feet, sun's bearing by compass S. ½ W.

The Greenwich date is June 1^d 0^h 21^m 20^s. True altitude, by Norie, 45° 3′ 0″.

Decl. 1st, 22° 5′ 56″ N., decl. 2nd, 22° 13′ 48″ N., daily var. + 7′ 52″, corr. + 0′ 7″, *Red. decl.* 22° 6′ 3″ W. Sum of logs. 19·217523, true azimuth S. 47° 56′ 8″ E.

True azimuth S. 47° 56′ 8″ E.
S. ½ point W. = Mag. azimuth S. 5 37 30 W.

Variation 53 33 38 W.

The *true azimuth* being to the *left* of magnetic.

Examples for Practice.

In each of the following examples it is required to find the true azimuth and variation :—

No.	Civil date, 1865.	M. T. ship.	Latitude.	Longitude.	Sun's bearing by compass.	Obs. alt. sun's L.L.	Ht. of eye.
1.	Jan. 24th,	$8^h 22^m 35^s$ A.M.	26° 5′ S.	50° 53′ W.	E.	38° 23′ 10″	16
2.	Feb. 28th,	3 14 0 P.M.	38 46 N.	97 16 W.	S. 42° 36′ W.	26 57 14	17
3.	Mar. 27th,	4 6 40 P.M.	4 22 N.	53 7 E.	W. ½ N.	29 30 50	20
4.	April 3rd,	6 20 0 P.M.	49 59 N.	169 58 E.	W. 14° 10′ S.	11 43 0	17
5.	May 27th,	9 3 20 A.M.	55 0 N.	1 33 W.	S. 36 0 E.	43 8 51	18
6.	June 20th,	6 10 0 P.M.	43 45 N.	11 26 W.	N. 50 20 W.	16 40 20	18
7.	July 31st,	8 46 30 A.M.	38 18 N.	65 4 W.	S. 69 20 E.	43 24 58	18
8.	Aug. 23rd,	5 54 58 A.M.	51 10 N.	135 40 W.	N. 56 20 E.	7 38 0	15
9.	Sept. 1st,	3 47 50 P.M.	10 40 S.	138 42 E.	W. by N ¾ N.	30 4 10	15
10.	Nov. 25th,	4 7 0 P.M.	39 58 S.	50 52 W.	W. 9° 10′ S.	33 51 0	14
11.	Dec. 17th,	9 10 30 A.M.	29 10 S.	26 53 W.	S. 79 20 E.	51 1 13	16
12.	July 3rd,	8 26 50 A.M.	32 10 S.	62 0 E.	N. 62 0 E.	14 11 37	19
13.	Jan. 6th,	5 2 14 P.M.	47 46 S.	33 11 E.	N. 64 40 W.	26 37 27	28
14.	April 25th,	7 56 41 A.M.	27 20 S.	86 43 W.	E. 12 10 N.	18 44 55	30
15.	Jan. 29th,	3 36 35 P.M.	42 26 N.	49 18 W.	W. 17 0 S.	13 38 46	16
16.	Feb. 1st,	3 44 51 P.M.	33 51 S.	20 37 E.	N. 70 50 W.	39 56 10	18
17.	Mar. 26th,	9 5 50 A.M.	43 6 N.	51 2 W.	S. 34 30 E.	32 40 0	18
18.	Feb. 26th,	2 48 0 P.M.	5 0 N.	167 0 E.	N. 128 15 W.	60 37 0	19
19.	June 21st,	3 22 0 P.M.	66 40 N.	55 20 W.	S. 50 0 W.	15 38 0	18
20.	Sept. 11th,	7 0 0 A.M.	37 0 S.	19 0 W.	N. 44 50 E.	42 28 0	20
21.	1866, Jan. 1st	9 27 10 A.M.	0 0	0 25 E.	S.E. by S.	45 10 50	17

ON FINDING THE LATITUDE BY REDUCTION TO THE MERIDIAN.

THE latitude of a place is most simply determined by observation of the meridian altitude of a known heavenly body. When such an observation cannot be obtained by reason of the state of the weather, the altitude of the body may often be obtained a little before or a little after its meridian passage. And if at the time of observing such an altitude near the meridian, the hour-angle of the body is known, we may find by computation very nearly the difference of altitude by which to reduce the observed to the meridian altitude. The correction is called the "Reduction to the Meridian." This method, in point of simplicity, is little inferior to the meridian altitude, to which it is next in importance. The term "near the meridian" implies a meridian distance limited according to the latitude and declination, and also the degree of precision with which the time is known.

RULE LX.

1°. *To the time shown by the watch, expressed astronomically, apply the error of the watch for apparent time:* adding *when the watch is* slow *(rejecting* 24^h *when the sum exceeds* 24^h *and putting the day one forward),* subtracting *when watch is* fast *(increasing the time shown by watch by* 24^h*, if necessary, and putting the day one back).*

2°. *Next turn into time the difference of longitude made since the error of the watch was determined;* adding *when the difference of longitude is* East, subtracting *when difference of longitude is* West: the result is apparent time at ship when the observation was made.

3°. *If apparent time at ship is* P.M., *it is the time from noon; when it is* A.M., *subtract it from* 24^h, *the remainder is the time from noon.*

Ex. 1. Suppose it is P.M. at ship, and the watch when *corrected* shows January $2^d\ 0^h\ 25^m\ 56^s$ (see example 1 following); then the time from noon is $25^m\ 56^s$ past noon of the 2nd.

Ex. 2. Again, suppose it is A.M. at ship, and the watch when *corrected* indicates February $5^d\ 23^h\ 17^m\ 16^s$ (see example 2 following), then we have

$$\left.\begin{array}{r} 24^h\ 0^m\ 0^s \\ 23\ \ 17\ \ 16 \\ \hline 42\ \ 44 \end{array}\right\}$$ In this instance it is $42^m\ 44^s$ before noon of the 6th.

4°. *With apparent time at ship and longitude, find Greenwich date in apparent time* (Rule XLII).

5°. *Take out of* Nautical Almanac, *page* 1, *the declination, and reduce it to the Greenwich date* (Rule XLIII or XLIV).

6°. *Correct the observed altitude of sun's upper or lower limb, and so get the true altitude of sun's centre* (Rule XLVIII).

7°. *Take out log. rising of time from noon* (Table 29, Norie),* *log. cos. declination* (Table 25, Norie), *and log. cos. of latitude* (Table 25, Norie).

8°. *Take the sum of these and find the natural number corresponding thereto.*

9°. *To the natural number just found add the natural sine of the true altitude* (Table 26, Norie): *the sum is natural cosine of meridian zenith distance, which take out of the Table, and name it* North *or* South, *according as the observer is* North *or* South *of the sun.*

10°. *Apply the reduced declination to the zenith distance, taking their* sum *if they are of the* same *name, but their* difference *if of* contrary *names: the result, in either case, is the latitude of the* same *name as the* greater.

By Raper.

1°. *Find the time from noon, as directed in the preceding rule.*

2°. *Get a Greenwich date by means of apparent time at ship and longitude.*

3°. *Reduce declination to Greenwich date.*

4°. *Correct the observed altitude, and so get the true altitude of sun's centre.*

5°. *With the latitude and declination find the logarithm in* Table 70, *to which add the logarithm sine square of the time from noon,* Table 69: *the sum is sine of the reduction, which take out of* Table 66.

6°. *Add the reduction to the true altitude: the result is the approximate meridian altitude.*

7°. To compute the 2nd reduction.—*Double the log. sine of the reduction, add to it log. tangent of meridian altitude found* (No. 6), *and the constant* 9·699; *the sum (rejecting* 10*) is the log. sine of 2nd reduction.*

8°. Subtract *the 2nd reduction from the approximate meridian altitude found* (No. 6); *the result is meridian altitude at the place where the altitude was observed.*

9°. *Having the meridian altitude, find the latitude as directed in* 10° *of the preceding Rule.*

---

* When the natural sine is used to 6 places, the index of the *log. rising* must be increased by 1, and when to 7 places, it must be increased by 2.

EXAMPLES.

Ex. 1. 1865, January 2nd, P.M. at ship, latitude account 52°6′ S., longitude 71° 23′ W. observed altitude sun's L.L. North of observer 60° 10′ 30″, index correction + 3′ 10″, height of eye 20 feet, time by watch 2ᵈ 5ʰ 48ᵐ 22ˢ, which was found to be 5ʰ 20ᵐ 16ˢ *fast* on apparent time at ship, difference of longitude 32·4 miles to West: required the latitude by reduction to meridian.

Time by watch, Jan.	2ᵈ 5ʰ48ᵐ22ˢ
Watch *fast*	— 5 20 16
	2 0 28 6
Diff. long. $\frac{32'{\cdot}4 \times 4}{60}$	— 2 10
Time from noon, Jan.	2 0 25 56

Ship date, Jan.	2ᵈ 0ʰ25ᵐ56ˢ
Long. in time	+ 4 45 32
Green. date, Jan.	2 5 11 28

By Raper: Index corr. + 3′ 10″, dip — 4′ 20″, ref. — 34″, par. + 4″, semid. + 16′ 18″, True altitude 60° 25′ 8″.

Obs. alt ☉'s L.L.	60° 10′ 30″
Index correction	+ 3 10
	60 13 40
Dip	— 4 17
	60 9 23
Corr. altitude	— 29
	60 8 54
Semi-diameter	+ 16 18
True altitude	60 25 12

Decl. page 1, N.A.	
2nd,	22° 53′ 41″ S.
3rd,	22 47 53 S.
log. 6168	5 48
log. 6656	5ʰ 11ᵐ
log. 1·2824	1 15
2nd,	22 53 41 S.
Red. decl,	22 52 26 S.

Norie.

Time from noon	25ᵐ56ˢ	rising	3·805830
Latitude	52 6	cos.	9·788370
Declination	22 52	cos.	9·964454
	3620	nat. no.	3·558654
			3620
True alt.	60° 25′ 12″	nat. sine	869668
Zen. dist.	29 9 25 S.	nat. cos.	873288
Decl.	22 52 26 S.		873347
Latitude	52 1 51 S.		239)5900(25″ &c.

Raper.

Lat. 52° S., decl. 23° S.		log.	0·369
Time from noon,	25ᵐ56ˢ	sin. sq.	7·505
1st reduction	+ 25′ 43″	sine	7·874
True altitude	60° 25 8		2
			5·748
Approx. M.A.	60 50 51	tang.	0·254
		const.	9·699
2nd reduction	— 10	sine	5·701
Meridian alt.	60 50 41		
Zenith dist.	29 9 19 S.		
Declination	22 52 26 S.		
Latitude	52 1 45 S.		

Ex. 2. 1865, February 6th, A.M. at ship, latitude account 51° 50′ N., longitude 118° 36′ W., observed altitude sun's L.L. South of observer 21° 50′, index correction + 56″, height of eye 22 feet, time by watch $6^d\ 4^h\ 4^m\ 4^s$, which was found to be $4^h\ 48^m\ 47^s$ *fast* on apparent time at ship, difference of longitude made to East was 29·8 miles since error of watch on apparent time at ship was determined: required the latitude by reduction to meridian.

Time by watch, Feb.	6^d	4^h	4^m	4^s
or,	5	28	4	4
Watch *fast*		— 4	48	47
	5	23	15	17
Diff. long. $\frac{29'{\cdot}8 \times 4}{60}$	+		1	59
App. time at ship, Feb.	5	23	17	16
		24	0	0
Time from noon, Feb.	6	0	42	44

App. time at ship, Feb.	5^d	23^h	17^m	16^s
Long. 118° 36′ W.	+	7	54	24
Greenwich date, Feb.	5	31	11	40
or,	6	7	11	40

By Raper: Index corr. + 56″, dip — 4′ 30″, ref. — 2′ 26″, par. + 8″, semid. + 16° 15′, True altitude 22° 0′ 23″.

Obs. alt. ☉'s L.L.	21° 50′ 0″
Index correction	+ 56
	21 50 56
Dip	— 4 30
	21 46 26
Corr. altitude	— 2 13
	21 44 13
Semi-diameter	+ 16 15
True altitude	22 0 28

Decl. apparent noon.		
	6th,	15° 30′ 31″ S.
	7th,	15 11 48 S.
log. 1080		18 43
log. 5229		$7^h 12^m$
log. 6309		5 37
		15 30 31 S.
Red. decl.		15 24 54 S.

Norie.

			1370
Time from noon	$42^m 44^s$	rising	4·237530
Latitude	51° 50′	cos.	9·790954
Declination	15 25	cos.	9·984085
	10326	nat. no.	4·013939
			10326
True alt.	22° 0′ 28″	nat. sine	374607
			125
Zen. dist.	67 21 10 N.	nat. cos.	385058
Decl.	15 24 54 S.		101
Latitude	51 56 16 N.		4300
		10″ =	448

Raper.

Latitude 52°, decl. 15½°			
(contrary names) T. 69		log.	0·108
Time from noon	$42^m 44^s$	sin. sq.	7·938
1st reduction	+ 38′ 13″	sine	8·046
True altitude	22° 0 23		2
			6·092
Approx. M. A.	22 38 36	tang.	9·620
		const.	9·699
2nd reduction	— 5	sine	5·411
Mer. altitude	22 38 31		
	90 0 0		
Zenith dist.	67 21 29 N.		
Declination	15 24 54 S.		
Latitude	51 56 35 N.		

Ex. 3. 1865, April 7th, A.M. at ship, latitude by account 58° 50′ N., longitude 58° 52′ W., observed altitude sun's L.L. South of observer 37° 42′ 15″, index correction — 54″, height of eye 10 feet, time by watch $7^d\ 0^h\ 59^m\ 50^s$, which had been found to be $1^h\ 22^m$ *fast* on apparent time at ship, the difference of longitude made to the *East* was 20·7 miles after the error on apparent time at ship was determined: required the latitude by reduction to meridian.

Time by watch, April	$7^d\ 0^h 59^m 50^s$
Watch *fast*	— 1 22 0
	6 23 37 50
Diff. long. $\frac{20'\cdot7 \times 4}{60}$	+ 1 23
App. time at ship, April	6 23 39 13
	24 0 0
Time from noon, April	7 0 20 47

App. time at ship, April	$6^d\ 23^h 39^m 13^s$
Long. 58° 52′ W.	+ 3 55 28
Greenwich date, April	7 3 34 41

By Raper: True altitude 37° 53′ 2″.

Obs. alt. ☉'s L.L.	37° 42′ 15″
Index correction	— 54
	37 41 21
Dip	— 3 2
	37 38 19
Corr. altitude	— 1 7
	37 37 12
Semi-diameter	+ 16 0
True altitude	37 53 12

	Decl. apparent noon.
7th,	6° 56′ 40″ N.
8th,	7 19 7 N.
log. 0290	22 27
log. 8259	$3^h 55^m$
log. 8549	+ 3 21
7th,	6 56 40 N.
Red. decl.	7 0 1 N.

Norie.

			1300
Time from noon	$20^m 47^s$	rising	3·612340
Latitude acct.	58° 50′	cos.	9·713935
Declination	7 0	cos.	9·996751
	2110	nat. no.	3·324326
		nat. no.	2110
True alt.	37° 53′ 12″	nat. sine	614056
			46
M.Z. dist.	51 57 36 N.	nat. cos.	616212
Decl.	7 0 1 N.		349
Latitude	58 57 37 N.		13700
		36″ =	380

Raper.

Lat. 59°, decl. 7° (same name) Table 70		log.	0·113
Time from noon	$20^m 47^s$	sin. sq.	7·313
1st reduction	+ 9′ 10″	sine	7·426
True altitude	37° 53 2		2
			4·852
Approx. M. A.	38 2 12	tang.	9·893
		const.	9·699
2nd reduction	— 1	sine	4·444
Mer. altitude	38 2 11		
	90 0 0		
Mer. zen. dist.	51 57 49 N.		
Declination	7 0 1 N.		
Latitude	58 57 50 N.		

Ex. 4. 1865, August 7th, A.M. at ship, latitude account, 40° 42′ N., longitude 36° 47′ W., observed altitude sun's L.L. South of observer was 65° 1′, index correction + 17″, eye 14 feet, time by watch $6^d\ 23^h\ 15^m\ 46^s$, which had been found to be $26^m\ 16^s$ *slow* of apparent time at ship, the difference of longitude made to the *East* was 17 miles after the error on apparent time at ship was determined: required the latitude.

Time by watch, Aug.	$6^d\,23^h\,15^m\,46^s$
Watch *slow*	+ 26 16
	6 23 42 2
Difference of longitude	+ 1 8
App. time at ship, Aug.	6 23 43 10
	24 0 0
Time from noon, Aug.	7 0 16 50

App. time at ship, Aug.	$6^d\,23^h\,43^m\,10^s$
Long. 36° 47′ W.	+ 2 27 8
Green. date, Aug.	7 2 10 18

By Raper: True altitude 65° 13′ 3″

Obs. alt. ⊙'s L.L.	65° 1′ 0″
Index correction	+ 17
	65 1 17
Dip	+ 3 36
	64 57 41
Corr. altitude	— 23
	64 57 18
Semi-diameter	+ 15 49
True altitude	65 13 7

	Decl. apparent noon.	
	7th,	16° 22′ 3″ N.
	8th,	16 5 4 N.
log. 1502		16 59
log. 1·0444		$2^h\,10^m$
log. 1·1946		1 32
	7th,	16 22 3 N.
Red. decl.		16 20 31 N.

Norie.

Time from noon	$16^m 50^s$	rising	3·430750
Latitude	40° 42′	cos.	9·879746
Declination	16 20½	cos.	9·982090
	1961	nat. no.	3·292586
		nat. no.	1961
True alt.	65° 13′ 7″	nat. sin.	907899
			14
M. Z. dist.	24 30 43 N.	nat. cos.	909874
Decl.	16 20 31 N.		
Latitude	40 51 14 N.		

Raper.

Lat. 41°, decl. 16½° (same name) Table 70		log.	0·545
Time from noon	$16^m 50^s$	sin. sq.	7·130
1st reduction	+ 16′ 16″	sine	7·675
True altitude	65° 13 3		2
			5·350
Approx. M. A.	65 29 19	tang.	0·341
		const.	9·699
2nd reduction	— 0 5	sine	5·390
Mer. altitude	65 29 14		
	90 0 0		
Zenith dist.	24 30 46 N.		
Declination	16 20 31 N.		
Latitude	40 51 17 N.		

Ex. 5. 1865, September 23rd, P.M. at ship, latitude account 51° 2′ N., longitude 161° 8′ E., observed altitude sun's L.L. South of observer 38° 44′ 20″, index correction + 1′ 7″, height of eye 21 feet, time by watch 23ᵈ 10ʰ 50ᵐ 0ˢ, which had been found to be 10ʰ 39ᵐ 2ˢ *fast* on apparent time at ship, difference of longitude made to *West* was 8·2 miles after the error on apparent time was determined: required the latitude.

Time by watch, Sep.	23ᵈ	10ʰ	50ᵐ	0ˢ
Watch *fast*	—	10	39	2
	23	0	10	58
Diff. of longitude	—			33
App. time at ship, Sep.	23	0	10	25
Time from noon 23rd is			10	25

App. time at ship, Sep.	23ᵈ	0ʰ	10ᵐ	25ˢ
Long. 161° 8′ E.	—	10	44	32
Greenwich date, Sept.	22	13	25	53

By Raper: Index corr. + 1′ 7″, dip — 4′ 25″, ref. — 1′ 13″, par. + 7″, semid. + 15′ 59″, True altitude 38° 55′ 55″.

Obs. alt. ☉'s L.L.	38°	44′	20″
Index correction	+	1	7
	38	45	27
Dip	—	4	23
	38	41	4
Corr. altitude	—	1	4
	38	40	0
Semi-diameter	+	15	59
True altitude	38	55	59

Decl. apparent noon.

22nd,	0°	12′	47″	N.
23rd,	0	10	37	S.
log. 0110		23	24	
log. 2520		13ʰ	26ᵐ	
log. 2630		13	6	S.
	0	12	47	N.
Red. decl.	0	0	19	S.

Norie.

Time from noon	10ᵐ 25ˢ	rising	3·013990
Latitude	51° 2′	cos.	9·798560
Declination	0 0	cos.	0·000000
	649	nat. no.	2·812550
		nat. no.	649
True alt.	38° 55′ 59″	nat. sine	628189
			224
M. Z. dist.	51 1 8 N.	nat. cos.	629062
Decl.	0 0 19 S.		94
Latitude	51 0 49 N.		3200
		8″ =	380

Raper.

Lat. 51°, decl. 0°, (different names) Table 70		log.	0·209
Time from noon	10ᵐ 25ˢ	sin. sq.	6·713
1st reduction	+ 2′ 52″	sine	6·922
True altitude	38° 55 55		2
			3·844
Approx. M. A.	38 58 47	tang.	9·908
		const.	9·699
2nd reduction	0 0	sine	3·451
Mer. altitude	38 58 47		
	90 0 0		
Zenith dist.	51 1 13 N.		
Declination	0 0 19 S.		
Latitude	51 0 54 N.		

Ex. 6. 1865, June 14th, A.M. at ship, latitude account 33° 48′ S., longitude 25° 20′ E., observed altitude sun's L.L. North of observer 32° 33′ 10″, index correction — 2′ 8″, eye 17 feet, time by watch $14^d\ 1^h\ 0^m\ 56^s$, which had been found to be $1^h\ 20^m\ 24^s$ *fast* on apparent time at ship, the difference of longitude made to the *East* was 11 miles: required the latitude by reduction to meridian.

Time by watch, June	$14^d\ 1^h\ 0^m 56^s$
Watch *fast*	— 1 20 24
	13 23 40 32
Diff. of longitude	+ 44
App. time at ship, June	13 23 41 16
	24 0 0
Time from noon, June	14 0 18 44

App. time at ship, June	$13^d 23^h 41^m 16^s$
Long. 25° 20′ E.	— 1 41 20
Green. date, June	13 21 59 56

By Raper: True altitude 32° 41′ 20″

Obs. alt. ☉'s L.L.	32° 33′ 10″
Index correction	— 2 8
	32 31 2
Dip	— 3 57
	32 27 5
Corr. altitude	— 1 22
	32 25 43
Semi-diameter	+ 15 47
True altitude	32 41 30

Decl. apparent noon.
13th, 23° 14′ 13″ N.
14th, 23 17 18 N.

log. 8912	3 5
log. 0378	$22^m\ 0^s$
log. 9290	2 50
	23 14 13 N.
Red. decl.	23 17 3 N.

Norie.

Time from noon	$18^m 44^s$	rising	3·52386
Latitude acct.	33° 48′	cos.	9·919593
Declination	23 17	cos.	9·963108
	2550	nat. no.	3·406561
		nat. no.	2550
True alt.	32° 41′ 30″	nat. sine	539996
			123
M. Z. dist.	57 8 4 S.	nat. cos.	542669
Decl.	23 17 3 N.		
Latitude	33 51 1 S.		

Raper.

Lat. 34°, decl. 23° (contrary names) Table 70		log.	0·260
Time from noon	$18^m 44^s$	sin. sq.	7·223
1st reduction	+ 10′ 27″	sine	7·483
True altitude	32° 41 20		2
			4·966
Approx. M. A.	32 51 47	tang.	9·810
		const.	9·699
2nd reduction	— 1	sine	4·475
Mer. altitude	32 51 46		
	90 0 0		
Mer. zen. dist.	57 8 14 S.		
Declination	23 17 3 N.		
Latitude	33 51 11 N.		

By Towson's Tables: Decl. 23° 20′, hour-angle $18^m\ 44^s$, give in Table 1, corr. 1 + 4′ 13″ and index 37″: then in Table 2, index 37″ and true altitude give + 6′ 4″, the sum + 10′ 17″ is the reduction.

Ex. 7. 1865, May 5th, P.M. at ship, latitude account 5° 13′ N., longitude 61° E., observed altitude sun's L.L. 78° 41′ N., eye 17 feet, time by watch $5^h\ 1^m\ 7^s$, which was found *fast* $4^h\ 50^m\ 57^s$, difference of longitude made since, 20½ miles West.

App. time at ship, May $5^d\ 0^h\ 8^m\ 48^s$ Green. date, app. time, May $4^d\ 20^h\ 4^m\ 48^s$

Time from noon is 8 48

Decl. 4th noon, 16° 3′ 0″ N.; decl. 5th noon, 16° 20′ 10″ N.; daily variation + 17′ 10″; correction + 14′ 22″; *Reduced declination* 16° 17′ 22″ N.

By Norie: True altitude 78° 52′ 47″. By Raper: True altitude 78° 52′ 47″.

Norie.

Time from noon	$8^m 48^s$	rising	2·867540
Latitude acct.	5° 13′	cos.	9·998197
Declination	16 17	cos.	9·982220
	705	log.	2·847957
		nat. no.	705
True alt.	78° 52′ 47″	nat. sine	981227
M. Z. dist.	10 54 31 S.	nat. cos.	981932
Decl.	16 17 22 N.		
Latitude	5 22 51 N.		

Raper.

Latitude 5° and declination 16⅓° (same name)		log.	0·989
Time from noon	$8^m 48^s$	sin. sq.	6·566
1st reduction	+ 12′ 14″	sine	7·555
True altitude	78° 52 47		2
			5·110
Approx. M. A.	79 5 1	tang.	0·715
		const.	9·699
2nd reduction	— 7	sine	5·524
Mer. altitude	79 4 54		
Mer. zen. dist.	10 55 6 S.		
Declination	16 17 22 N.		
Latitude	5 22 16 N.		

Examples for Practice.

Ex. 1. 1865, January 4th, A.M. at ship, latitude by account 34° 47′ N., longitude 27° 12′ W., observed altitude sun's L L. South of the observer was 32° 12′ 10″, index corr. + 4′ 19″, height of eye 28 feet, time by watch $4^d\ 0^h\ 13^m\ 24^s$, which had been found to be $25^m\ 35^s$ *fast* of apparent time at ship, difference of longitude made to *West* was 29′·2 after the error on apparent time at ship was determined: required the latitude.

Ex. 2. 1865, February 28th, P.M. at ship, lat. acct. 43° 46′ N., long. 12° 31′ W., obs. alt. sun's L.L. 38° 1′ 15″ S., index corr. — 5′ 10″, eye 23 feet, time by watch $28^d\ 1^h\ 2^m\ 3^s$, which had been found to be $48^m\ 14^s$ *fast* of app. time at ship, diff. of long. made to *East* was 14′ after error of app. time at ship was found: required the latitude.

Ex. 3. 1865, March 21st, A.M. at ship, lat. acct. 41° 24′ S., long. 105° E., obs. alt. sun's L.L. 47° 46′ N., index corr. + 26″, eye 22 feet, time by chron. $20^d\ 16^h\ 58^m\ 12^s$, which had been found to be $6^h\ 34^m\ 34^s$ *slow* on app. time at ship, diff. of long. made to *East* was 23′ after error on app. time at ship was determined: required the latitude.

Ex. 4. 1865, April 21st, A.M. at ship, lat. acct. 39° 54′ N., long. 6° 6′ E., obs. alt. sun's L.L. 61° 26′ 35″ S., index corr. + 1′ 0″, eye 18 feet, time by watch $21^d\ 0^h\ 8^m\ 10^s$, which had been found to be $27^m\ 10^s$ *fast* of app. time at ship, diff. of long. made to *East* was 5′ after the error on app. time at ship was determined.

Ex. 5. 1865, May 29th, P.M. at ship, lat. acct. 37° 15′ S., long. 107° W., obs. alt. sun's L.L. 30° 22′ 30″ N., index corr. + 49″, eye 22 feet, time by watch $29^d\ 7^h\ 9^m\ 11^s$, which had been found to be $6^h\ 36^m\ 56^s$ *fast* on app. time at ship, diff. of long. made to *West* was 27′ after the error on app. time at ship was determined.

Ex. 6. 1865, June 19th, A.M. at ship, lat. acct. 44° 24′ N., long. 14° 5′ W., obs. alt. sun's L.L. 68° 37′ 5″ South of observer, eye 18 feet, time by watch $18^d\ 20^h\ 40^m\ 40^s$, which was found to be $3^h\ 2^m\ 2^s$ *slow* on app. time at ship, diff. of long. made to *East* was 32′·5 after error on app. time at ship was determined.

Ex. 7. 1865, July 16th, P.M. at ship, lat. acct. 0° 38′ S., long. 2° E., obs. alt. sun's L.L. 67° 41′ (zen. S.), eye 15 feet, time by watch $0^h\ 11^m\ 9^s$, found *fast* on app. time at ship 56^s, diff. of long. made since 1½′ to East.

Ex. 8. 1865, August 30th, P.M. at ship, lat. acct. 41° 5′ N., long. 139° 25′ E., obs. alt. sun's L.L. 57° 20′ S., index corr. + 2′ 21″, eye 14 feet, time by watch $29^d\ 22^h\ 22^m\ 22^s$, found to be $2^h\ 0^m\ 18^s$ *slow* of app. time at ship, diff. of long. made to *West* was 34′.

Ex. 9. 1865, Sept. 9th, P.M. at ship, lat. acct. 9° 20′ S., long. 178° 30′ E., obs. alt. sun's L.L. 85° 19′ (zen. N.), eye 20 feet, time by watch $11^h\ 59^m\ 40^s$, *slow* on app. time at ship $9^m\ 21^s$, diff. of long. made to *East* was 10½′.

Ex. 10. 1865, Oct. 11th, P.M. at ship, lat. acct. 45° 51′ N., long. 85° 3′ E., obs. alt. sun's L.L. 36° 38′ 15″ S., index corr. — 5′ 15″, eye 16 feet, time by watch $10^d\ 18^h\ 50^m\ 10^s$ which was $5^h\ 40^m\ 12^s$ *slow* on app. time, diff. of long 33′ *West*.

Ex. 11. 1865, Nov. 3rd, P.M. at ship, lat. acct. 32° S., long. 109° 39′ E., obs. alt. sun's L.L. 71° 50′ N., index corr. + 32″, eye 18 feet, time by watch $2^d\ 22^h\ 22^m$, which was found 2^h *slow*, diff. of long. 28′·7 *West*.

Ex. 12. 1865, Dec. 23rd, A.M. at ship, lat. acct. 47° 22′ S., long. 27° 3′ W., obs. alt. sun's L.L. 65° 10′ 15″ N., index corr. + 45″, eye 12 feet, time by watch $22^d\ 22^h\ 59^m\ 42^s$, found to be $28^m\ 40^s$ *slow*, diff. of long. was 36′ *East*.

Ex. 13. 1865, Jan. 5th, P.M. at ship, lat. acct. 8° 50′ N., long. 130° 14′ W., obs. alt. sun's L.L. 58° 6′ 10″ S., eye 21 feet, time by watch $0^h\ 2^m\ 40^s$, found $13^m\ 48^s$ *slow* on app. time, diff. long. made since 16′ *East*.

Ex. 14. 1865, April 28th, A.M. at ship, lat. acct. 18° 46′ S., long. 34° 12′ W., obs. alt. sun's L.L. 56° 18′ (zen. S.), index corr. + 1′ 5″, eye 21 feet, time by watch $11^h\ 40^m\ 50^s$, found *fast* $2^m\ 17^s$ on app. time at ship, diff. long. made since 17½′ *West*.

Ex. 15. 1865, July 13th, A.M. at ship, lat. acct. 54° 35′ S., long. 152° 20′ W., obs. alt. sun's L.L. 13° 17′ N., index corr. + 47″, eye 12 feet, time by watch $13^d\ 7^h\ 54^m\ 12^s$, which had been found to be $8^h\ 14^m\ 17^s$ *fast* on app. time at ship, diff. of long. made to *West* was 34′ after error on app. time was determined.

Ex. 16. 1865, March 20th, A.M. at ship, lat. acct. 19° S., long. 33° 33′ W., obs. alt. sun's L.L. 70° 21′ N., index corr. — 2′ 10″, eye 16 feet, time by chron. $20^d\ 7^h\ 48^m\ 17^s$, found *fast* on app. time at ship $8^h\ 6^m\ 11^s$, diff. of long. made since 14½′ *East*.

Ex. 17. 1865, April 12th, A.M. at ship, lat. acct. 0°, long. 164° 12′ W., obs. alt. sun's L.L. 80° 36′ N., index corr. — 5′ 10″, eye 21 feet, time by watch $12^d\ 0^h\ 0^m\ 2^s$, *fast* on app. time at ship $10^m\ 51^s$, diff. of long. made to *East* was 7½′.

Ex. 18. 1865, Sept. 16th, A.M. at ship, lat. acct. 42° 36′ S., long. 137° 10′ E., obs. alt. sun's L.L. 44° 6′ N., index corr. + 2′ 10′, eye 19 feet, time by watch $16^d\ 8^h\ 41^m\ 43^s$, which had been found to be $9^h\ 2^m\ 47^s$ *fast* of app. time at ship, the diff. of long. made to *West* was 14′ after the error on app. time at ship was determined.

Ex. 19. 1865, March 16th, A.M. at ship, lat. acct. 37° 42′ N., long. 61° 40′ E., obs. alt. sun's L.L. 50° 0′ 30″ S., index corr. + 34″, eye 15 feet, time by watch $10^h\ 53^m\ 31^s$, found *slow* on app. time at ship $1^h\ 3^m\ 22^s$, diff. of long. made since 18′ *West.*

Ex. 20. 1865, December 31st, A.M. at ship, lat. acct. 52° N., long. 12° 53′ W., obs. alt. sun's L.L. 14° 46′ S., eye 19 feet, time by watch $0^h\ 56^m$, which was *fast* on app. time at ship $1^h\ 5^m\ 20^s$, diff. of long. 21′·4 *West.*

Ex. 21. 1865, March 5th, P.M. at ship, lat. acct. 33° 35′ N., long. 78° E., obs. alt. sun's L.L. 49° 53′ 15″ S., index corr. — 3′ 15″, eye 22 feet, time by watch $4^d\ 19^h\ 2^m\ 12^s$, found to be $5^h\ 17^m\ 12^s$ *slow*, diff. of long. was 10′ *East.*

Ex. 22. 1865, September 22nd, A.M. at ship, lat. acct. 45° 45′ S., long. 111° 42′ W., obs. alt. sun's L.L. 43° 50′ N., index corr. — 5′ 40″, height of eye 18 feet, time by watch $23^d\ 7^h\ 41^m\ 10^s$, found to be $8^h\ 4^m\ 10^s$ *fast*, diff. of long. was 13′·5 *East.*

Ex. 23. 1865, December 23rd, P.M. at ship, lat. acct. 42° 16′ N., long. 4° 39′ W., obs. alt. sun's U.L. 24° 14′ 10″ S., eye 11 feet, time by watch $0^h\ 50^m\ 58^s$, *fast* on app. time at ship $19^m\ 38^s$, diff. of long. 21′·3 *West.*

ON FINDING THE LATITUDE BY A MERIDIAN ALTITUDE OF A FIXED STAR.

RULE LXI.

1°. *Take from* Nautical Almanac *the star's declination.*

2°. *To the observed altitude apply the index error, as the sign attached directs.*

3°. Subtract *the dip answering to the height of eye* (Table 5, Norie; Table 30, Raper).

4°. Subtract *the refraction* (Table 4, Norie; Table 31, Raper), *and thus get the true altitude.*

5°. Subtract *the true altitude from* 90°; *the remainder is the zenith distance.*

6°. *Mark the zenith distance* N. *or* S., *according as the observer is* North *or* South *of the star.*

7°. *Underneath this last place the declination, and take their* sum *if they have the* same *names; but take their* difference, *if they have* unlike *names; the result, in either case, will be the latitude.*

The declination of a fixed star changes so slowly that it may be taken out of the *Nautical Almanac* by *inspection*, without any practical error resulting; a Greenwich date, therefore, is clearly unnecessary.

8°. *When the zenith distance and declination are of the* same *name, the latitude is of* that name; *when the zenith distance and declination are of* different *names, the latitude takes the name of the* greater.

The stars are inserted in the *Nautical Almanac* in the order of their Right Ascension, from 0^h to 24^h; it will, therefore, very much facilitate the finding of the given star in the *Nautical Almanac*, to turn, in the first instance, to the three pages (324—326, *Nautical Almanac*, 1865) and thence obtain the star's Right Ascension, which find at the top of one of the pages following (327—385, *Nautical Almanac*, 1865), which will give the star, and the declination will be found opposite the day in the side column which is *nearest* the given day. The degrees (°) and minutes (′) are placed at the top of the column (as annexed), and the seconds (″) are ranged below, for the sake of economizing space in the second column below the name of the star. If the seconds exceed 60″, only take the excess of 60″ and increase the minutes (′) at the top by 1′. Thus, on January 21st, the declination of Andromedæ is 28° 20′ 52″ N., and on October 18th, the declination is 28° 21′ 11″ N.,—70″·7 being 1′ 11″, which last added to 28° 20′, which stands at the head of the column, gives the declination.

Date.	α Andromedæ.	
	R.A	Decl. N.
	$0^h\ 1^m$	28° 20′
Jan. 1	$25^s{\cdot}50$	54″·6
11	25·35	53·5
21	25·21	52·2
31	25·09	50·7
&c.	&c.	&c.
Oct. 8	29·20	69·2
18	29·17	70·7
&c.	29·12	71·9

EXAMPLES.

Ex. 1. 1865, Dec. 29th, long. 140° W., the obs. mer. alt of the star α Leonis (*Regulus*), bearing South, was 52° 7′ 30″, index corr. — 27″, height of eye 15 feet: required the latitude.

Observed altitude of star	52°	7′	30″	
Index correction	—		27	
	52	7	3	
Dip 15 feet	—	3	42	
	52	3	21	
Refraction	—		44	
True altitude	52	2	37	
	90	0	0	
Zenith distance	37	57	23	N.
Declination (N.A., p. 355)	12	37	4	N.
Latitude	50	34	27	N.

By Raper: Index cor. — 27″, dip — 3′ 50″, ref. — 46″, true alt. 52° 2′ 27″, Latitude 50° 34′ 37″ N.

Ex. 2. 1865, March 12th, long. 10° E., obs. mer. alt. of the star *Pollux*, bearing North, was 71° 59′ 10″, index corr. + 1′ 15″, height of eye 18 feet: required the latitude.

Observed altitude of star	71°	59′	10″	
Index correction	+	1	15	
	72	0	25	
Dip 18 feet	—	4	4	
	71	56	21	
Refraction	—		18	
True altitude	71	56	3	
	90	0	0	
Zenith distance	18	3	57	S.
Declination (N.A. p. 351)	28	20	48	N.
Latitude	10	16	51	N.

By Raper: Index corr. + 1′ 15″, Dip — 4′ 10″, ref. — 19″, true alt. 71° 55′ 56″, Latitude 10° 16′ 44″ N.

Ex. 3. 1865, Feb. 18th, long. 84° W., the obs. mer. alt. of the star *a* Argus *(Canopus)*, bearing South, was 37° 26′, index corr. + 1′ 17″, height of eye 16 feet.

Observed altitude of star	37° 26′ 0″
Index correction	+ 1 17
	37 27 17
Dip	— 3 50
	37 23 27
Refraction	— 1 15
True altitude	37 22 12
	90 0 0
Zenith distance	52 37 48 N.
Declination (N.A. p. 348)	52 37 48 S.
Latitude	0 0 0

By Raper: Index corr. + 1′ 17′, dip — 4′ 0″, ref. — 1′ 16″, true alt. 37° 21′ 1″, Latitude 0° 0′ 11″ N.

Ex. 4. 1865, Jan. 1st, long. 100° E., the obs. mer. alt. of the star *a* Canis Majoris *(Sirius)*, bearing South, was 59° 59′ 50″ index corr. + 4′ 12″, height of eye 24 feet.

Observed altitude of star	59° 59′ 50″
Index correction	+ 4 12
	60 4 2
Dip 24 feet	— 4 42
	59 59 20
Refraction	— 33
True altitude	59 58 47
	90 0 0
Zenith distance	30 1 13 N.
Declination (N.A. p. 349)	16 32 12 S.
Latitude	13 29 1 N.

By Raper: Index corr. + 4′ 12″, dip — 4′ 50″, ref. — 34″, true alt. 59° 58′ 38″, Latitude 13° 29′ 10″ N.

Examples for Practice.

In each of the following examples it is required to find the latitude :—

No.	Civil Date, 1865.	Long.	Star	Obs. Alt.	Corr.	Eye.
1.	Nov. 7th,	90° W.	*a* Andromedæ	75° 10′ 30″ S.	+ 0′ 27″	25ft.
2.	Jan. 1st,	27 W.	*a* Aurigæ *(Capella)*	54 0 15 N.	— 1 45	18
3.	Aug. 19th,	84 E.	*a* Lyræ *(Vegra)*	50 0 20 N.	0 0	22
4.	Dec. 22nd,	82 E.	*a* Persci	51 51 45 S.	+ 0 40	26
5.	April 11th,	142 W.	*a* Virginas *(Spica)*	63 14 30 S.	+ 3 47	22
6.	June 10th,	151 E.	*a* Eridani *(Achernar)*	40 10 25 S.	+ 0 55	24
7.	Dec. 27th,	91 W.	*(Algenib)*	78 16 45 S.	— 0 25	24
8.	Nov. 30th,	24 W.	*a* Arietis	68 23 0 N.	— 1 38	28
9.	Feb. 2nd,	76 E.	*a* Tauri *(Aldebaran)*	29 52 10 N.	+ 5 20	15
10.	June 1st,	97 E.	a^1 Crucis	75 10 30 S.	— 1 40	14
11.	May 22nd,	178 W.	*a* Hydræ	30 28 53 S.	— 7 38	11
12.	July 17th,	29 E.	*a* Cygni	20 13 50 N.	0 0	18
13.	Oct. 17th,	165 E.	*a* Aquilæ *(Altair)*	60 49 10 N.	+ 0 55	17
14.	March 2nd,	154 W.	*a* Canis Majoris *(Sirius)*	58 58 50 N.	+ 1 10	20
15.	April 3rd,	111 E.	*a* Bootis *(Arcturus)*	79 49 40 S.	— 2 5	25
16.	Aug. 7th,	40 W.	*a* Scorpii *(Antares)*	68 49 30 S.	— 1 54	21
17.	May 1st,	8 E.	a^2 Centauri	10 2 50 S.	— 0 45	20
18.	Oct. 29th,	5 W.	*a* Piscis Australis *(Fomalhaut)*	70 6 0 N.	+ 0 55	12
19.	Mar. 31st,	36 E.	*a* Pegasi *(Markab)*	33 20 50 N.	+ 1 20	20
20.	Sept. 11th,	12 W.	*a* Casscipea	62 24 50 N.	— 7 30	19

ORDINARY EXAMINATION.

EXAMINATION PAPER.—No. I.

FOR SECOND MATE.

1. Multiply 498 by 637, by common logarithms.
2. Divide 143613 by 591, by common logarithms.

3.—

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	W.S.W.	4	8	N.W.	½	A point, in lat. 37° 3′ N., long. 9° 0′ W., bearing by compass N.E. ¼ E., distance 15 miles.
2		5	4			
3		5	4			
4		5	4			
5	N.W. ½ N.	5	2	W.S.W.	¼	
6		5	3			
7		5	3			
8		5	2			
9	N.N.W.	4	6	W.	¾	
10		4	5			
11		4	5			
12		4	4			Variation 2 points West.
1	N.W. by W.	3	8	S.W. by W.	1¼	
2		3	6			
3		3	4			
4		4	2			
5	S.W. ½ S.	3	3	S.S.E.	1	
6		3	3			
7		3	2			
8		3	2			A current set by compass S.W. by W. ¾ W., 8 miles, from the time the departure was taken to the end of the day.
9	W. ½ S.	4	3	S. by W.	½	
10		4	2			
11		4	2			
12		4	3			

Correct the courses for variation and leeway, and find the course and distance from the given point, and the latitude and longitude in by inspection.

4. 1865, January 1st, in longitude 109° 41′ W., the observed meridian altitude of sun's L.L. was 59° 59′ 50″, bearing South, index error + 50″, height of eye 15 feet: required the latitude.

5. In latitude 59° 58′ N., the departure made good was 124 miles: required the difference of longitude by parallel sailing.

6. Required the course and distance from A to Tynemouth Light, by Mercator's sailing.

Lat. A	57° 57′ N.	Long. A	7° 12′ E.
Lat. Tynemouth Light	55 1 N.	Long. Tynemouth Light	1 25 W.

ADDITIONAL FOR ONLY MATE.

7. 1865, January 6th, find the times of high water at Cherbourg, A.M. and P.M.

7*a*. 1864, Jan. 6th, find A.M. and P.M. tides at Cherbourg *(Admiralty Tide Tables)*.

7*b*. 1865, January 2nd, find A.M. and P.M. tides at New Calabar River, longitude 7° E., change tide $5^h\ 0^m$ (By Rule LIII, page 151).

8. 1865, January 1st, at $8^h\ 4^m$ A.M. apparent time at ship, in latitude 50° 32′ N., longitude 139° 51′ W., the sun's magnetic amplitude E. by S. ½ S.: required the true amplitude and variation.

9. 1865, January 29th, P.M. at ship, latitude 42° 26′ N., observed altitude sun's L.L. 13° 40′, index error — 1′ 14″, height of eye 16 feet, time by chronometer $29^d\ 6^h\ 48^m\ 40^s$, which was $8^m\ 7^s$ *slow* for Greenwich mean noon, January 1st, and *gaining* $6^s{\cdot}3$ daily: required the longitude by chronometer.

ADDITIONAL FOR FIRST MATE.

10. 1865, January 15th, mean time at ship $9^h\ 39^m\ 44^s$ A.M., latitude 23° 39′ S., longitude 127° 52′ W., sun's magnetic azimuth S. 93° E., observed altitude sun's L.L. 55° 8′ 30″, index error — 2′ 30″, height of eye 12 feet: required the true azimuth and variation.

11. 1865, January 17th, P.M. at ship, latitude by account 36° 2′ N., longitude 149° 28′ E., observed altitude sun's L.L. South of observer was 32° 54′ 15″, index error + 2′ 18″, height of eye 22 feet, time by watch $16^d\ 23^h\ 0^m$, which had been found to be $1^h\ 19^m\ 24^s$ *slow* on apparent time at ship, the difference of longitude made to the *West*, since the error of watch on apparent time at ship was determined, was 39′·2 required the latitude by reduction to meridian.

ADDITIONAL FOR MASTER ORDINARY.

12. 1865, January 24th, the observed meridian altitude of the star *α* Tauri *(Aldebaran)* was 52° 36′ bearing South, index correction — 23″, height of eye 20 feet: required the latitude.

13. Correct the following compass courses for deviation, as given at page 17:— N.N.W., N., and N.E. by N.

EXAMINATION PAPER.—No. II.

FOR SECOND MATE.

1. Multiply 537 by 6·98, by common logarithms.

2. Divide 999·432 by 67·8, by common logarithms.

3.—

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	S.E. by E.	7	2	N.	0	A point in lat. 47° 31′ N., long. 52° 33′ W., bearing by compass W.S.W., distance 18 miles.
2		7	3			
3		7	5			
4		7				
5	S.E.	7		E.N.E.	½	
6		6	5			
7		6	4			
8		6	1			
9	E. by N.	5	8	S.E. by S.	1	
10		5	8			
11		5	4			
12		5				Variation 2½ points West.
1	E.N.E.	4	8	S.E.	1½	
2		4	7			
3		4	5			
4		4				
5	S.S.E.	3	8	E.	2	
6		3	8			
7		3	4			
8		4				
9	S.E. by S.	5		E. by N.	1¼	A current set by compass S. by E., 12 miles, from the time the departure was taken to the end of the day.
10		5	3			
11		5	4			
12		5	3			

4. 1865, February 1st, in longitude 78° 14′ E., the observed meridian altitude of sun's L.L. was 78° 4′ 10″, bearing South, index error + 55″, height of eye 12 feet: required the latitude.

5. In latitude 47° 30′ N., the departure made good was 115·5 miles: required the difference of longitude by parallel sailing.

6. Required the course and distance from St. Helena to Cape Horn, by calculation on Mercator's principle.

Latitude St. Helena	15° 55′ S.	Longitude St. Helena	5° 44′ W.
Latitude Cape Horn	55 59 S.	Longitude Cape Horn	67 16 W.

ADDITIONAL FOR ONLY MATE.

7. 1865, February 15th: required the times high water at Aberdeen, A.M. and P.M.

7*a*. 1864, February 11th: find A.M. and P.M. tides at Shields *(Admiralty Tide Tables)*.

7*b*. 1865, February 7th, find A.M. and P.M. tides at Halifax, longitude 64° W., change tide $8^h\ 0^m$ apparent time (by Method III).

8. 1865, February 20th, at $6^h\ 9^m$ P.M. apparent time at ship, latitude 11° 58′ S., longitude 179° 42′ E., sun's magnetic amplitude W.S.W.: required the variation.

9. 1865, February 10th, A.M. at ship, latitude 50° 48′ N., observed altitude sun's L.L. 9° 10′ 50″, index correction — 3′ 20″, height of eye 18 feet, time by chronometer $9^d\ 9^h\ 59^m\ 25^s$, which was $34^m\ 12^s$ *fast* for mean noon at Greenwich, January 10th, and *losing* $10^s\cdot 8$ daily: required the longitude.

ADDITIONAL FOR FIRST MATE.

10. 1865, February 16th, mean time at ship $8^h\ 7^m\ 35^s$ A.M., latitude 51° 2′ N., longitude 140° 34′ W., sun's magnetic azimuth S. 36° 20′ E., observed altitude sun's L.L. 7° 16′ 40″, index correction — 6′ 10″, height of eye 15 feet: required the variation.

11. 1865, February 15th, A.M. at ship, latitude acct. 55° 59′ S., longitude 54° 18′ E., observed altitude sun's L.L. North of observer was 46° 22′ 10″, index correction — 1′ 50″, height of eye 19 feet, time by watch $15^d\ 3^h\ 0^m\ 5^s$, which had been found to be $3^h\ 30^m$ *fast* on apparent time at ship, the difference of longitude made to *East* was 16′·8: required the latitude.

ADDITIONAL FOR MASTER ORDINARY.

12. 1865, February 12th, the observed meridian altitude of star Procyon, South of observer, was 77° 18′ 10″, index correction + 19″, height of eye 16 feet: required the latitude.

13. Correct the following compass courses for deviation, as given in page 73: S. by E. ½ E., W. by S. ¾ S.

EXAMINATION PAPER.—No. III.

FOR SECOND MATE.

1. Multiply 488 by 62·8, by common logarithms, and prove the result.
2. Divide 666·666 by 8·88, by logarithms, and prove the result by decimals.

3.—

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	S.S.E.	5	4	E.	2¼	A point of land in lat. 62° N. long. 150° E., bearing by compass W. by S. ¼ S., distance 17 miles.
2		5	6			
3		4	9			
4		4	8			
5	S.S.W. ½ W.	4	7	W.	2¾	
6		4	8			
7		5	2			
8		5	3			
9	W.S.W.	5		S.	2½	
10		6				
11		6	5			
12		6	5			Variation 2¾ points East.
1	W. ½ N.	6	6	N. by E.	0	
2		7				
3		6	4			
4		6				
5	E.	4	6	S.S.E.	2½	
6		5				
7		4	8			
8		4	6			A current set the ship by compass N.N.E., 21 miles, from the time the departure was taken to the end of the day.
9	E.S.E.	4		S. by W.	0	
10		4	5			
11		4	5			
12		5				

4. 1865, March 20th, longitude 173° 18′ W., the observed meridian altitude of sun's L.L. was 89° 38′ 10″ bearing North, index correction + 4′ 27″, height of eye 18 feet: required the latitude.

5. In latitude 34° 28′ S., the departure made good was 394·2 miles: required the difference of longitude by parallel sailing.

6. Required the course and distance from the Cape of Good Hope to Cape Frio.

Lat. Cape Good Hope	34° 28′ S.	Long. Cape Good Hope	18° 28′ E.
Lat. Cape Frio	23 0 S.	Long. Cape Frio	41 57 W.

ADDITIONAL FOR ONLY MATE.

7. 1865, March 17th, find the times of high water at Cowes, A.M. and P.M.

7*a*. 1864, March 2nd, find times high water A.M. and P.M. at Havre (*Admiralty Tide Tables*).

7*b*. 1865, March 9th, find times high water at Calcutta, long. 88° 27′ E., change tide 3^h 5^m (by Method III).

8. 1865, March 6th, at 5^h 31^m 52^s P.M. apparent time at ship, in latitude 52° 12′ N., longitude 138° 54′ E., the sun's magnetic amplitude was W. ¾ S.: required the variation.

9. 1865, March 31st, A.M. at ship, latitude 26° 9′ N., observed altitude sun's L.L. 29° 10′ 20″, height of eye 26 feet, time by chronometer 31^d 0^h 4^m 50^s, which was 58^m 58^s *fast* for mean noon at Greenwich, Nov. 20th, 1864, and *gaining* 5·8 daily: required the longitude.

ADDITIONAL FOR FIRST MATE.

10. 1865, March 10th, mean time at ship, 7^h 35^m 25^s A.M., latitude 42° 41′ S., longitude 148° 5′ E., sun's bearing by compass S. 108° 37′ 30″ E., observed altitude sun's L.L. 17° 57′ 40″, height of eye 19 feet: required the variation.

11. 1865, March 25th, P.M. at ship, latitude acct. 20° 1′ N., longitude 89° 10′ E., observed altitude sun's L.L. South of observer was 71° 9′, height of eye 18 feet, time by watch 24^d 17^h 38^m 12^s, which had been found to be 6^h 31^m 8^s *slow* on apparent time at ship, the difference of longitude made to *East* was 13½ miles, after the error on apparent time was determined: required the latitude by reduction to meridian.

ADDITIONAL FOR MASTER ORDINARY.

12. 1865, March 19th, the observed meridian altitude of *a* Bootis (*Arcturus*), 36° 10′ 20″, bearing North, index correction + 2′ 42″, height of eye 20 feet: required the latitude.

13. Correct the following compass courses for deviation, as given at page 73:— W. ¾ S., E. by N. ½ N.

EXAMINATION PAPER.—No. IV.

FOR SECOND MATE.

1. Multiply, by common logarithms, 456 by 28.

2. Divide, by common logarithms, 46292 by 142.

3.—

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	S.W. ½ W.	3	5	S. by E. ½ E.	2	A point, in lat. 50° 12′ S.,
2		3	2			long. 179° 40′ W., bearing
3		3	6			by compass N. ¾ W., dis-
4		3	7			tance 19 miles.
5	N. ¾ E.	5	4	E.N.E.	¼	
6		5	6			
7		5	6			
8		4	8			
9	S. by E. ½ E.	2	4	S.W. ½ W.	2¾	
10		2	3			
11		2	2			
12		2				
1	W. by S.	3	2	S. by W.	2¼	Variation 1½ point East.
2		3				
3		2	6			
4		2	8			
5	E.N.E.	2	4	S.E.	2½	
6		2	3			
7		2	4			
8		2	3			
9	S.S.W. ½ W.	3	6	S.E.	1¾	A current set by compass
10		3	7			S.W. ½ W., 22½ miles, from
11		3	2			the time the departure was
12		3	4			taken to the end of the day.

4. 1865, April 1st, in longitude 87° 42′ W., observed meridian altitude sun's L.L. South of observer was 48° 42′ 30″, index correction + 1′ 42″, height of eye 18 feet: required the latitude.

5. In latitude 49° 57′ N., the departure made good was 149 miles: required the difference of longitude by parallel sailing.

6. Required the course and distance from A to B.

Latitude A	56° 35′ S.	Longitude A	2° 15′ E.
Latitude B	51 10 S.	Longitude B	3 10 W.

ADDITIONAL FOR ONLY MATE.

7. 1865, April 21st, required the times of high water at Chatham, A.M. and P.M.

7*a*. 1864, April 10th, find A.M. and P.M. tides at New York, longitude 74° W. *(Admiralty Tide Tables.)*

7*b*. 1865, April 30th, required the times of high water A.M. and P.M. at A, longitude 100° W., change tide $4^h\ 10^m$ apparent time (by Method III).

8. 1865, April 28th, at $5^h\ 14^m\ 2^s$ P.M. apparent time at ship, latitude 38° 19′ S., longitude 88° 48′ E., sun's magnetic amplitude N.W. by W.: required the variation.

9. 1865, April 15th, P.M. at ship, latitude 37° 49′ S., observed altitude sun's L.L. was 26° 27′ 30″, index correction — 49″, height of eye 13 feet, time by chronometer $14^d\ 22^h\ 48^m\ 17^s$, which was $54^m\ 51^s$ *fast* for Greenwich mean noon, January 22nd, and *losing* $11^s{\cdot}3$ daily: required the longitude.

ADDITIONAL FOR FIRST MATE.

10. 1865, April 17th, mean time at ship $2^h 49^m 45^s$ P.M., latitude 39° 50′ N., longitude 1° 35′ E., sun's bearing by compass W. 6° S., observed altitude sun's L.L. 42° 10′, index correction — 45″, height of eye 14 feet: required the variation.

11. 1865, April 19th, A.M. at ship, latitude account 46° 15′ N., longitude 178° 12′ E., observed altitude of sun's L.L. South of observer 54° 7′, index correction + 2′ 12″, height of eye 20 feet, time by watch $18^d 21^h 24^m 22^s$, which had been found to be $2^h 5^m$ *slow* on apparent time at ship, the difference of longitude made to the *East* was 30 miles, after the error on apparent time was determined.

ADDITIONAL FOR MASTER ORDINARY.

12. 1865, April 12th, the observed meridian altitude of the star Spica, South of observer, was 20° 58′ 40″, index correction — 45″, height of eye 25 feet: required the latitude.

13. Correct the following courses for local deviation, as given at page 73:—W. by S., West, N. by E., East.

EXAMINATION PAPER.—No. V.

FOR SECOND MATE.

1. Multiply 767 by 89·8, by common logarithms.
2. Divide 66889·2 by 99·7, by common logarithms.
3.—

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	S.S.E. ½ E.	3		S.W.	2¼	A point, in lat. 64° 2′ S., long. 140° 21′ E., bearing by compass W. by N. ¾ N., distance 12 miles.
2		3	2			
3		3	4			
4		2	7			
5	E. by S. ¾ S.	2	4	N.E.	3	
6		3	3			
7		3	4			
8		3	5			
9		3	4			
10	W.N.W.	4	2	N.	2¾	
11		4	3			
12		4	4			
1	N.N.E. ¼ E.	5	6	N.W.	1¾	Variation 3½ points East.
2		5	5			
3		5	3			
4	W.S.W.	2	6	N.W.	3¼	
5		2	4			
6		2	3			
7	N.N.W.	3	7	W.	2	
8		3	6			
9		3	4			A current set by compass N. by E. ¼ E., 29 miles from the time the departure was taken to the end of the day.
10	S.S.W.	6	5	W.	1½	
11		6	7			
12		7	2			

4. 1865, May 8th, in longitude 105° 17′ W., observed meridian altitude of sun's L.L. bearing North was 76° 3′, index correction — 1′ 27″, height of eye 10 feet: required the latitude.

5. In latitude 3° 24′ N., the departure made good was 982 miles: required the difference of longitude by parallel sailing.

6. Required the course and distance from A to B, by calculation on Mercator's principle.

Latitude A	39° 39′ N.	Longitude A	51° 51′ E.
Latitude B	27 27 N.	Longitude B	33 33 E.

ADDITIONAL FOR ONLY MATE.

7. 1865, May 22nd, find the times of high water A.M. and P.M. at Margate Pier, Berwick, and Downs (stream).

7*a*. 1864, May 18th, find A.M. and P.M. tides at Aberdeen (*Admiralty Tide Tables*).

7*b*. 1865, May 8th, find A.M. and P.M. times of high water at A, longitude 20° E., change tide $2^h\ 58^m$.

8. 1865, May 21st, at $7^h\ 29^m$ A.M. apparent time at ship, latitude 45° 53′ S., longitude 50° 39′ E., sun's magnetic amplitude N.N.E. ½ E.: required the variation.

9. 1865, May 22nd, A.M. at ship, latitude 43° 25′ N., observed altitude sun's L.L. 32° 8′, index correction + 47″, height of eye 15 feet, time by chronometer $21^d\ 21^h\ 6^m\ 10^s$, which was $2^m\ 45^s$ *fast* for mean noon at Greenwich, April 1st, and *gaining* $4^s.8$ daily: required the longitude.

ADDITIONAL FOR FIRST MATE.

10. 1865, May 25th, mean time at ship $3^h\ 29^m\ 47^s$ P.M., latitude 41° 58′ N., longitude 96° 1′ W., sun's bearing by compass N. 108° 30′ W., observed altitude sun's L.L. 40° 40′ 40″, index correction + 2′ 15″, height of eye 12 feet: required the variation.

11. 1865, May 10th, P.M. at ship, latitude account 28° 13′ S., longitude 112° 15′ W., observed altitude of sun's L.L. North of observer was 43° 35′ 20″, index correction — 6′ 12″, height of eye 19 feet, time by watch $10^d\ 7^h\ 20^m\ 26^s$, which had been found to be $6^h\ 56^m\ 45^s$ *fast* on apparent time at ship, the difference of longitude made to the *East* was 26′, after the error on apparent time was determined: required the latitude.

ADDITIONAL FOR MASTER ORDINARY.

12. 1865, May 10th, the observed meridian altitude of Spica, bearing North, was 70° 10′ 25″, index correction + 42″, height of eye 22 feet: required the latitude.

13. Correct the following courses for the local deviation, as given in page 73:— E.S.E., N.N.W., W.S.W., N.E.

EXAMINATION PAPER.—No. VI.

FOR SECOND MATE.

1. Multiply 588 by 867, by common logarithms.

2. Divide 396694 by 898, by common logarithms.

3 —

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	E. ¾ N.	6	3	S. by E.	3¼	A point, in lat. 56° 12′ N.,
2		6	3			long. 135° 40′ W., bearing
3		6	3			by compass W.S.W., dis-
4		6				tance 22½ miles.
5	N.W. ½ N.	5	1	S. by W.	0	
6		4	8			
7		4	8			
8	W.N.W.	4	9	N.	3	
9		5	7			
10	N. ½ W.	5	8	W.N.W.	2¼	
11		5	9			
12		6	5			Variation 2¼ points East.
1	E. ¾ S.	6	4	S.	1¾	
2		6	3			
3	W.S.W.	6	2	S.	2	
4		5	7			
5	S.W. ¾ W.	4	8	S. by E.	3½	
6		5	1			
7		5				
8		4	5			A current set by compass
9	S. by W.	4	5	W. by S.	2¼	S. by W. ¼ W., 16 miles,
10		4	5			from the time the departure
11	N.W. by N.	3	9	W. by S.	2½	was taken to the end of the
12		4	2			day.

4. 1865, June 1st, in longitude 96° 17′ E., the observed meridian altitude of sun's L.L. was 75° 38′ 15″ bearing North, index correction + 27″, height of eye 26 feet: required the latitude.

5. In latitude 35° 54′ S., departure made good, 249 miles: required the difference of longitude.

6. Required the course and distance from A to B, by Mercator's sailing.

Latitude of A	3° 19′ N.	Longitude of A	71° 42′ W.
Latitude of B	33 2 S.	Longitude of B	122 20 W.

ADDITIONAL FOR ONLY MATE.

7. 1865, June 21st, find the times of high water, A.M. and P.M., at King's Road, Montrose, Leith Pier, Tay Bar, and North Shields.

7*a*. 1864, June 21st, find A.M. and P.M. tides at Rotterdam and Heligoland (M. II.).

7*b*. 1865, June 12th, find time high water at Rio Janeiro (43° 12′ W.), change tide $2^h\ 40^m$ P.M.

8. 1865, June 10th, at $4^h\ 45^m$ P.M. apparent time at ship, latitude 36° 42′ S., longitude 120° 30′ E., sun's magnetic amplitude N.W. ¾ W.: required the true amplitude and variation.

9. 1865, June 15th, P.M. at ship, latitude 2° 2′ S., observed altitude sun's L.L. 28° 38′, index correction + 48″, height of eye 12 feet, time by chronometer $15^d\ 0^h\ 3^m\ 18^s$, which was $2^h\ 24^m\ 19^s$ *fast* for mean noon at Greenwich, April 30th, and *losing* $8^s.3$ daily: required the longitude.

ADDITIONAL FOR FIRST MATE.

10. 1865, June 8th, mean time at ship $7^h\ 50^m$ A.M., latitude 15° 45′ N., longitude 32° 33′ W., sun's bearing by compass S. 93° E., observed altitude sun's L.L. 31° 10′, index correction — 1′ 22″, height of eye 18 feet: required the variation.

11. 1865, June 5th, P.M. at ship, latitude account 61° 58′ N., longitude 155° 21′ E., observed altitude sun's L.L. South of observer was 49° 50′ 30″, index correction + 2′ 10″, height of eye 21 feet, time by watch $4^d\ 23^h\ 48^m\ 26^s$, which had been found to be $50^m\ 10^s$ *slow* on apparent time at ship, the difference of longitude made to *West* was 17′·5, after the error on apparent time was determined.

ADDITIONAL FOR MASTER ORDINARY.

12. 1865, June 11th, the observed meridian altitude of the star Pollux, bearing North, was 48° 40′ 24″, index correction — 1′ 32″, height of eye 20 feet.

13. Correct the following courses for local deviation, as given in page 73:— N.W. by W., E. by N., S.S.E., S.W. ½ W.

EXAMINATION PAPER.—No. VII.

FOR SECOND MATE.

1. Multiply 483 by 28·7, by common logarithms.
2. Divide 242880 by 704, by common logarithms.
3.—

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	S.E. by S.	6		S.W. by S.	1¼	A point, in lat. 51° 25′ N.,
2		5	6			long. 9° 29′ W., bearing by
3		5	4			compass N.E. by N., dis-
4		5				tance 17 miles.
5	S.	3	2	W.S.W.	2¾	
6		3	3			
7	N.W.	3		W.S.W.	3¼	
8		2	8			
9	W.	6	6	S.S.W.	¾	
10		6	4			
11		6	5			
12		6	5			
1	S.S.E.	4	4	S.W.	1½	Variation 2½ points West.
2		4	4			
3		4	2			
4		4				
5	S.W. by W.	7		S. by E.	½	
6		6	6			
7		6	4			
8		7	4			
9	S.S.E.	7	4	E.	¼	A current set by compass
10		7	2			N.W. by N., 9 miles, from
11	S.	7	6		0	the time the departure was
12		8	2			taken to the end of the day.

4. 1865, July 26th, in longitude 12° 19′ W., the observed meridian altitude of the sun's L.L. was 15° 41′, bearing North, index correction — 3′ 10″, height of eye 19 feet: required the latitude.

5. In latitude 25° 20′ S., the departure made good was 389 miles: required the difference of longitude by parallel sailing.

6. Required the course and distance from the Start Point to St. Michael's.

Latitude Start Point	50° 13′ N.	Longitude Start Point	3° 38′ W.
Latitude St. Michael's	37 48 N.	Longitude St. Michael's	25 10 W.

ADDITIONAL FOR ONLY MATE.

7. 1865, July 15th, find the times of high water at Bristol, A.M. and P.M.

7a. 1864, July 25th, required A.M. and P.M. times of high water at Glasgow (*Admiralty Tide Tables*).

7b. 1865, July 6th, find A.M. and P.M. tides at A, long. 110° E., change tide $1^h\ 40^m$.

8. 1865, July 12th, at $5^h\ 9^m$ P.M. apparent time at ship, latitude 29° 3′ S., longitude 21° 53′ W., the sun's magnetic amplitude was N.W. ¾ W.: required the variation.

9. 1865, July 17th, P.M. at ship, latitude 31° 32′ S., observed altitude sun's L.L. 13° 23′ 10″, index correction + 5″, eye 16 feet, time by chronometer $16^d\ 22^h\ 23^m\ 49^s$, which was $29^m\ 17^s$ *fast* for mean noon at Greenwich, June 6th, and *losing* $5^s{\cdot}8$ daily: required the longitude.

ADDITIONAL FOR FIRST MATE.

10. 1865, July 4th, mean time at ship, $8^h\ 39^m\ 2^s$ A.M. latitude 38° 10′ S., longitude 78° 35′ W., sun's bearing by compass N. 30° E., the observed altitude sun's L.L. 12° 16′ 10″, index correction — 2′ 38″, height of eye 14 feet: required the true azimuth and variation.

11. 1865, July 31st, P.M. at ship, latitude account 45° 5′ S., longitude 83° 12′ E., observed altitude sun's L.L. North of observer was 26° 15′ 10″, index correction — 40″, height of eye 19 feet, time by watch $30^d\ 18^h\ 50^m$, which had been found to be $5^h\ 36^m\ 16^s$ *slow* on apparent time at ship, the difference of longitude made to *West* was 14 miles after the error on apparent time was determined.

ADDITIONAL FOR MASTER ORDINARY.

12. 1865, July 6th, the observed meridian altitude of the star *a* Scorpii (*Antares*), bearing North, was 70° 10′ 30″, height of eye 21 feet: required the latitude.

13. Correct the following compass courses for deviation, as given in page 73:— N. ½ E., N. ½ W.

EXAMINATION PAPER.—No. VIII.

FOR SECOND MATE.

1. Multiply 777 by 999, by common logarithms.

2. Divide 111111 by 234, by common logarithms.

3.—

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1						
2	S.S.E.	9	2	S.W.	1	A point, in lat. 0° 10′ N.,
3		8	4			long. 173° 50′ E., bearing
4		8	4			by compass S.W., distance
5	W.N.W.	7	3	S.W.	1½	15 miles.
6		7				
7		6	7			
8		6	1			
9	W. ½ N.	5	4	S.W. by S.	2	
10		5	5			
11		5	6			
12		5	5			
1	S. by E. ¾ E.	6	3	S.W.	1½	Variation ¾ point East.
2		6	3			
3		6	2			
4		6	2			
5	S.S.E.	5	2	S.W.	1¾	
6		5	3			
7		5	5			
8		6				
9	W. by N.	9	6	S.S.W.	0	A current set the ship
10		10	4			S. by W., 18 miles, from the
11		11	5			time the departure was taken
12		11	5			to the end of the day.

4. 1865, August 12th, in longitude 92° 12′ E., observed meridian altitude sun's L.L. bearing North was 42° 42′ 10″, index correction — 2′ 50″, height of eye 17 feet: required the latitude.

5. In latitude 56° 11′ S., the departure made good was 356 miles East: required the difference of longitude by parallel sailing.

6. Required the course and distance from A to B, by Mercator's sailing.

Latitude of A 47° 50′ S. Longitude of A 42° 16′ E.
Latitude of B 40 49 S. Longitude of B 46 25 E.

ADDITIONAL FOR ONLY MATE.

7. 1865, August 17th, required the times of high water at Liverpool Dock, A.M. and P.M.: and also at Dungeness.

7*a*. 1864, August 25th, find A.M. and P.M. tides at Cardiff and Lundy Island.

7*b*. August 21st, find A.M. and P.M. tides, long 70° E., change tide $2^h\ 7^m$.

8. 1865, August 1st, at $6^h\ 57^m$ P.M. apparent time at ship, latitude 37° 3′ N., longitude 105° 49′ E., sun's magnetic amplitude N.W. by W. ¾ W.: required the variation.

9. 1865, August 7th, P.M. at ship, latitude 6° 4′ N., observed altitude sun's L.L. 24° 5′, index correction + 1′ 30″, height of eye 12 feet, time by chronometer $6^d\ 20^h\ 10^m\ 36^s$, which was $20^m\ 10^s$ *slow* for Greenwich mean noon, July 21st, and *losing* $6^s{\cdot}6$ daily: required the longitude.

ADDITIONAL FOR FIRST MATE.

10. 1865, August 20th, mean time at ship $2^h\ 35^m\ 25^s$ P.M., latitude 52° 2' S., longitude 89° 26' E., sun's bearing by compass N. ½ W., the observed altitude of sun's L.L. 17° 26', index correction + 1' 45", height of eye 21 feet: required the variation.

11. 1865, August 11th, A.M. at ship, latitude account 39° 3' S., longitude 157° 25' E., observed altitude sun's L.L. North of observer was 34° 37', height of eye 12 feet, time by watch $10^d\ 19^h\ 41^m\ 25^s$, which had been found to be $3^h\ 41^m\ 8^s$ *slow* on apparent time at ship, the difference of longitude made to the *East* was 33', after the error on apparent time was determined.

ADDITIONAL FOR MASTER ORDINARY.

12. 1865, August 20th, the observed meridian altitude of the star *α* Aquilæ *(Altair)* bearing North, was 66° 51' 10", index correction + 58", height of eye 13 feet: required the latitude.

13. Correct the following compass courses for deviation, as given in page 73:— W. ¾ S., N.W. ¼ N.

EXAMINATION PAPER.—No. IX.

FOR SECOND MATE.

1. Multiply 1368 by 84, by common logarithms.
2. Divide 138876 by 426, by common logarithms.

3.—

H.	COURSES.	K	$\frac{1}{10}$	WINDS.	LEE-WAY.	REMARKS, &c.
1	S.W.	6	4	S.S.E.	½	A point, Naze of Norway, in latitude 57° 57' N., long. 7° 12' E., bearing by compass E. ½ N., distance 14 miles.
2		6	5			
3		6	7			
4	W.N.W.	7	4	S.W.	¼	
5		7	3			
6		7	3			
7	S.S.W. ¼ W.	4	4	W.	1	
8		4	5			
9		4	3			
10	N.N.W. ½ W.	3	6	W.	1½	
11		3	4			
12	S.W. by W.	3	2	N.W. by W.	2¼	
1		2	6			Variation 2¼ points West.
2		2	6			
3	N.W. ¼ W.	1	5	W.S.W.	3	
4		1	6			
5		1	4			
6	W. by S.	4	5	N.W. by N.	1¾	
7		4	6			
8		4	7			
9	N.W. by N.	3		W. by S.	2¾	A current set by compass N.N.E., 32 miles, from the time the departure was taken to the end of the day.
10		2	6			
11	W.S.W.	4	3	S.	1½	
12		4	7			

4. 1865, September 22nd, in longitude 123° 45′ W., the observed meridian altitude of sun's L.L., bearing North, was 89° 49′ 50″, index correction +52″, height of eye 26 feet: required the latitude.

5. In latitude 20° 15′ S., the departure made good was 352 miles West: required the difference of longitude by parallel sailing.

6. Required the course and distance from A to B, by Mercator's sailing.

Latitude of A 25° 39′ N.	Longitude of A 48° 19′ W.
Latitude of B 34 28 S.	Longitude of B 18 28 E.

ADDITIONAL FOR ONLY MATE.

7. 1865, September 14th, find the times of high water at Swansea, Cork, Donegal Bar, Dungarvon, and Fowey, A.M. and P.M.

7*a*. 1864, September 14th, find A.M. and P.M. tides at Alderney and Cherbourg.

7*b*. 1865, September 14th, longitude 89° W.: find A.M. and P.M. tides at A, change tide $4^h\ 50^m$ apparent time (Method III).

8. 1865, September 19th, at $6^h\ 3^m$ A.M. apparent time at ship, latitude 35° 36′ S., longitude 36° 38′ W., sun's magnetic amplitude East: required the variation.

9. 1865, September 1st. P.M. at ship, latitude 9° 9′ N., observed altitude sun's L.L. 62° 13′ 14″, index correction + 15″, height of eye 16 feet, time by chronometer, August $31^d\ 15^h\ 16^m\ 28^s$, which was $20^m\ 12^s$ *slow* for Greenwich mean noon, July 28th, and *gaining* $2^s{\cdot}6$ daily.

ADDITIONAL FOR FIRST MATE.

10. 1865, September 16th, mean time at ship $8^h\ 3^m\ 18^s$ A.M., latitude 4° 22′ N., longitude 81° 39′ W., sun's bearing by compass N. 81° 20′ E., the observed altitude sun's L.L. 29° 30′ 30″, index correction + 1′ 22″, height of eye 20 feet: required the true azimuth and variation.

11. 1865, September 23rd, A.M. at ship, latitude account 27° 32′ S., longitude 168° 51′ E., observed altitude sun's L.L., North of observer, was 61° 59′ 40″, index correction — 1′ 50″, eye 18 feet, time by watch $22^d\ 23^h\ 10^m\ 10^s$, which had been found to be $31^m\ 31^s$ *slow* on apparent time at ship, difference of longitude since made to *East* was 20·4 miles.

ADDITIONAL FOR MASTER ORDINARY.

12. 1865, September 7th, the observed meridian altitude of the star Arcturus was 86° 35′ 50″, bearing North, index correction — 1′ 10″, eye 12 feet.

13. Correct the following compass courses for deviation, as given at page 73:— N. ¾ E. and E. by S. ½ S.

EXAMINATION PAPER.—No. X.

FOR SECOND MATE.

1. Multiply 33·9 by 56·7, by common logarithms.

2. Divide 8491·92 by 98·4, by common logarithms.

3.—

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	W.S.W.	4		S.	½	A point, Cape Farewell,
2		4				in latitude 59° 49′ N., longi-
3		4	4			tude 43° 54′ W., bearing by
4		4	6			compass N.W., distance 16
5	W.	5		S.S.W.	1	miles.
6		5				
7		4	5			
8		4	5			
9	S.E.	4		S.S.W.	1½	
10		4	2			
11		4	4			
12		4	4			
1	S. by E.	3		S.W. by W.	2¼	
2		2	5			Variation 6¼ points West.
3		2				
4		1	5			
5	S.W. by S.	1	5	S.E. by S.	3¼	
6		1	5			
7	Calm.	..	.	Calm.		
8						
9	W. ½ N.	3		S.S.W. ½ W.	2½	
10	S.W.	3	6	W.N.W.	1¾	A current set by compass
11		4	4			S.S.E., 21 miles, during the
12		5				24 hours.

4. 1865, October 20th, in longitude 150° 25′ W., the observed meridian altitude of sun's L.L., bearing North, was 49° 58′ 50″, index correction + 1′ 10″, eye 19 feet: required the latitude.

5. In latitude 22° 22′ N, the departure made good was 222·2 miles East: required the difference of longitude.

6. Required the course and distance from A to B, by Mercator's sailing.

Latitude of A	9° 36′ S.	Longitude of A	2° 10′ W.
Latitude of B	7 16 S.	Longitude of B	1 24 E.

ADDITIONAL FOR ONLY MATE.

7. 1865, October 13th, find the times of high water at Falmouth, Eyemouth, Dunkerque, and Orfordness, A.M. and P.M.

7*a*. 1864, October 11th, find A.M. and P.M. times of high water at Calcutta, longitude 88° E. (Method II.)

7*b*. 1865, October 30th, find A.M. and P.M. times of high water at A, longitude 92° E., change tide 4^h 10^m (Method III).

8. 1865, October 9th, at 5^h 51^m A.M. apparent time at ship, latitude 18° 45′ S, longitude 99° 18′ E., sun's magnetic amplitude E. ¾ S.: required the variation.

9. 1865, October 30th, A.M. at ship, latitude 12° 53′ S., observed altitude of sun's L.L. 28° 45′ 50″, index correction + 30″, eye 20 feet, time by chronometer 30^d 4^h 6^m 8^s, which was 10^m 12^s *fast* for Greenwich mean noon, July 17th, and *gaining* $5^s{\cdot}7$ daily.

ADDITIONAL FOR FIRST MATE.

10. 1865, October 1st, mean time at ship 4^h 54^m P.M., latitude 17° 8′ S., longitude 152° 33′ E., sun's bearing by compass W. ¾ S., observed altitude of sun's L.L. 13° 59′, index correction — 22″, eye 17 feet: required the variation.

11. 1865, October 2nd, A.M. at ship, latitude by account 38° 12′ N., longitude 23° 34′ W., observed altitude of sun's L.L., South of observer, 47° 30′, index correction — 1′ 38″, eye 17 feet, time by watch 2^d 1^h 50^m, which had been found to be 2^h 10^m *fast* on apparent time at ship, difference of longitude made to *East* was 43 miles.

ADDITIONAL FOR MASTER ORDINARY.

12. 1865, October 7th, the observed meridian altitude of the star *α* Pegasi (*Markab*) was 54° 10′ 15″, bearing South, height of eye 13 feet: required the latitude.

13. Correct the following courses for local deviation, as given at page 73:— N.W. ¾ W., N. by E. ¼ E., N. ¾ W., and N.E. ½ E.

EXAMINATION PAPER.—No. XI.

FOR SECOND MATE.

1. Multiply 987·6 by 67, by common logarithms.
2. Divide 8888·88 by 999·9, by common logarithms.

3.—

H.	Courses.	K	1/10	Winds.	Lee-way.	Remarks, &c.
1	N. by E.	4	2	E. by N.	2¼	A point, in lat. 52° N., long. 120° E., bearing by compass N. by E. ¼ E., distance 16 miles.
2		3	8			
3		4	5			
4		4	5			
5	N.E. ¾ E.	4	5	N. by W.	3½	
6		5				
7		5	1			
8		4	8			
9	W. ¾ N.	5	7	N.	1¾	
10		6	2			
11		6	3			
12		6	4			Variation 2¼ points East.
1		6	5			
2	E.S.E.	5	9	S.	3	
3		5	8			
4		5	7			
5	S.E. ½ S.	4	6	N. by E.	0	
6		4	5			
7		4	8			
8		5	1			
9	W. ¾ S.	6		N.W. by N.	3¼	A current set by compass E.N.E., 22·5 miles, from the time the departure was taken to the end of the day.
10		6	3			
11		6	3			
12		6	3			

4. 1865, November 15th, in longitude 80° 11′ E., the observed meridian altitude of sun's L.L. bearing North was 67° 44′, index correction + 1′ 38″, eye 15 feet: required the latitude.

5. In latitude 40° 50′ S., the departure made good was 149′ East: required the difference of longitude by parallel sailing.

6. Required the course and distance from the ship's position to the Lizard, by calculation on Mercator's principle.

Latitude of position	17° 50′ N.	Longitude of position	76° 42′ W.
Latitude of Lizard	49 58 N.	Longitude of Lizard	5 12 W.

ADDITIONAL FOR ONLY MATE.

7. 1865, November 5th, required the times of high water at Pentland Firth, Boulogne, and Dieppe, A.M. and P.M.

7*a*. 1864, November 30th, find A.M. and P.M. times of high water at Bombay, longitude 73° E. (Method II.)

7*b*. 1865, November 1st, find times high water A.M. and P.M. at A, longitude 151° E., change tide 8^h 15^m (Method III).

8. 1865, November 10th, at 4^h 3^m 52^s A.M. apparent time at ship, latitude 58° 13′ S., longitude 55° 47′ E., the sun's magnetic amplitude was S. by E. ¾ E.: required the variation.

9. 1865, November 30th, A.M. at ship, latitude 40° 40′ S., observed altitude sun's L.L. 39° 30′, index correction + 6′ 24″, eye 22 feet, time by chronometer 30^d 2^h 58^m 45^s, which was 10^m 36^s *fast* for Greenwich mean noon, October 25th, and *losing* $1^s.2$ daily: required the longitude.

ADDITIONAL FOR FIRST MATE.

10. 1865, November 15th, mean time at ship 2^h 46^m 43^s P.M., latitude 45° 31′ S., longitude 119° 56′ W., sun's bearing by compass S. 93½° W., the observed altitude sun's L.L. 43° 45′, index correction — 56″, eye 20 feet: required the variation.

11. 1865, November 13th, A.M. at ship, latitude account 50° 52′ S., longitude 48° 52′ W., observed altitude of sun's L.L. was 56° 0′ N., index correction + 23″, eye 19 feet, time by watch 13^d 3^h 4^m 34^s, which had been found to be 3^h 43^m 24^s *fast* on apparent time at ship, the difference of longitude made to *West* was 9′, after the error on apparent time was determined.

ADDITIONAL FOR MASTER ORDINARY.

12. 1865, November 7th, the observed meridian altitude of the star *α* Piscis Australis *(Fomalhaut)*, bearing North, was 59° 40′, index correction + 1′ 12″, eye 23 feet: required the latitude.

13. Correct the following compass courses for deviation, as given in page 73:—
S.E. ½ E., S.W. ¾ W., N.E. by E. ½ E.

EXAMINATION PAPER.—No. XII.

FOR SECOND MATE.

1. Multiply 53·7 by 6·98, by common logarithms.
2. Divide 999·43 by 67·832, by common logarithms.

3.—

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	E.N.E. ¾ E.	2	5	N. ½ E.	2	A point, in lat. 50° 0′ N.,
2		3	3			long. 40° 0′ W., bearing by
3		4	1			compass E.N.E. ¼ E., dis-
4		3	2			tance 16 miles.
5	W.N.W.	3	5	N.	1½	
6		4	2			
7		3	6			
8		3	7			
9	S.S.W. ¼ W.	4	2	W.	2½	
10		4	1			
11		3	6			
12		3	2			Variation 3¼ points West.
1	N.N.W. ¼ W.	4	1	W.	1¾	
2		3	2			
3		4	1			
4		4	1			
5	S.E. ¾ E.	4	2	S.S.W.	1½	
6		3	6			
7		3	7			
8		4	1			
9	S.W. ¾ W.	2	5	S. by E. ¼ E.	3¾	A current set by compass
10		4	2			S.S.W., 6 miles, from the
11		4	1			time the departure was taken
12		5	2			to the end of the day.

4. 1865, December 31st, in longitude 123° 45′ W., the observed meridian altitude of sun's L.L., bearing South, was 67° 8′ 10″, index correction + 9″, height of eye 13 feet: required the latitude.

5. In latitude 60° N., the departure made good was 111 miles East: required the difference of longitude by parallel sailing.

6. Required the course and distance from Port San Francisco to Cape Palliser.

Lat. Port San Francisco	37° 48′ N.	Long. Port San Francisco	122° 24′ W.
Lat. Cape Palliser	41 38 S.	Long. Cape Palliser	175 21 E.

ADDITIONAL FOR ONLY MATE.

7. 1865, December 15th, find the times of high water at the Nore Light, Goree, Brouwershaven, and Dunbar, A.M. and P.M.

7a. 1864, Dec. 31st, find A.M. and P.M. tides at Batavia, long. 107° E. (Method II).

7b. 1865, December 18th, find A.M. and P.M. tides at A, longitude 96° E., change tide 12^h 30^m apparent time (Method III).

8. 1865, December 28th, at 4^h 11^m 13^s A.M. apparent time at ship, lat. 46° 47′ S., long. 179° 54′ W., sun's magnetic amplitude E. by S. ¾ S.: required the variation.

9. 1865, December 24th, A.M. at ship, latitude 33° 33′ S., observed altitude sun's L.L. 40° 40′ 40″, index correction + 2′ 20″, eye 19 feet, time by chronometer 8^h 2^m 7^s P.M., which was 6^m $7^s.8$ *slow* for Greenwich mean noon, October 31st, and *losing* $5^s.7$ daily: required the longitude.

ADDITIONAL FOR FIRST MATE.

10. 1865, December 27th, mean time at ship $8^h\ 0^m\ 10^s$ A.M., latitude 15° 12′ N., longitude 130° W., sun's bearing by compass S.E. by E. ¾ E., the observed altitude of sun's L.L. 20° 15′, index correction + 2′ 5″, eye 16 feet: required the variation.

11. 1865, December 4th, A.M. at ship, latitude acct. 51° 54′ S., longitude 30° 10′ W., observed altitude sun's L.L. 59° 59′ N., index correction — 3′ 12″, eye 20 feet, time by watch $4^d\ 2^h\ 12^m\ 10^s$, which had been found to be $2^h\ 42^m\ 10^s$ *fast* on apparent time at ship, the difference of longitude made to *West* was 10 miles, after the error on apparent time was determined.

ADDITIONAL FOR MASTER ORDINARY.

12. 1865, December 21st, the observed meridian altitude of star *α* Canis Minoris *(Procyon)*, bearing North, 52° 51′ 50″, index correction — 49″, eye 21 feet: required the latitude.

13. Correct the following compass courses for deviation, as given in page 73: N. 80° E., S. 45° W., N. 11° 15′ W., E. 20° N.

EXAMINATION PAPER.—No. XIII.

FOR SECOND MATE.

1. Multiply 86 by 67, by common logarithms.
2. Divide 34594 by 426, by common logarithms.

3.—

H.	Courses.	K	1/10	Winds.	Lee-way.	Remarks, &c.
1	S.W. ¾ W.	2	6	S.E. by E. ¼ E.	2¼	A point, in lat. 36° 35′ S., long. 110° 25′ W., bearing by compass E. by N. ¼ N., distance 18 miles.
2		3	5			
3		4	3			
4	W. by S. ½ S.	3	2	S. by W.	2½	
5		4	4			
6		2	3			
7	W. by N. ½ N.	2	5	S.W.	2	
8		3	3			
9		4	1			
10	S.W.	5	4	W.N.W.	1¾	
11		4	2			
12		4	4			
1	N.W. ½ W.	3	2	W. by S. ½ S.	2½	Variation 1¾ point East.
2		4	1			
3		5	4			
4		3	2			
5	W. by S.	3	2	S. ½ W.	1½	
6		4	1			
7	S. by E. ½ E.	4	2	S.W. ½ S.	2	
8		3	4			
9	S.W.	3	4	S. by E.	2½	
10		5	2			A current set by compass E. ½ S., the last 8 hours, at the rate of 2 miles an hour.
11		2	6		3¼	
12		3	5			

4. 1865, August 11th, in longitude 92° 12′ E., observed meridian altitude sun's L.L. 42° 42′ 10″, zenith South of sun, index correction — 2′ 50″, height of eye 17 feet: required the latitude.

5. In latitude 46°, departure 98 miles: find the difference of longitude.

6. Required the course and distance from A to B, by Mercator's sailing.

Latitude of A 51° 30′ N.	Longitude of A 3° 30′ 30″ W.
Latitude of B 20 0 N.	Longitude of B 35 4 56 W.

ADDITIONAL FOR ONLY MATE.

7. 1865, June 21st, find A.M. and P.M. tides at Eddystone, Harwich, and Tay Bar.

7*a*. 1864, July 12th, find time of high water at Point de Galle, longitude 80° E.

7*b*. 1865, April 13th, find the time of high water at A, longitude 148° W., change tide 3^h apparent time.

8. 1865, October 28th, at 8^h 30^m A.M. apparent time at ship, latitude 49° 40′ N., longitude 116° 12′ W., sun's bearing by compass E. 3° 20′ N.: required the variation.

9. 1865, April 18th, A.M. at ship, latitude 50° 48′ N., observed altitude sun's L.L. 38° 10′ 50″, index correction + 45″, height of eye 16 feet, time by chronometer $9^h 27^m 2^s$ A.M. at Greenwich, which was $1^m 58^s{\cdot}7$ *fast* on Greenwich mean noon April 1st, and *gaining* $11^s{\cdot}2$ daily: required the longitude.

ADDITIONAL FOR FIRST MATE.

10. 1865, March 9th, mean time at ship 8^h 11^m 42^s A.M., latitude 29° 58′ S., longitude 57° 24′ E., observed altitude of sun's L.L. 28° 23′ 15″, height of eye 16 feet, sun's azimuth E. 9° 40′ S.: required the variation.

11. 1865, July 28th, A.M. at ship, latitude account 38° 54′ N., longitude 39° W., observed altitude of sun's L.L. 69° 10′ S., index correction + 1′ 27″, height of eye 23 feet, time by watch 11^h 3^m 15^s, *slow* on apparent time 28^m 45^s, difference of longitude made to the *East* was 32 miles: required the latitude.

ADDITIONAL FOR MASTER ORDINARY.

12. 1865, October 8th, the observed meridian altitude of *α* Gruis was 50° 0′ S., index correction — 1′ 12″, height of eye 17 feet: required the latitude.

13. Correct the following courses for the local deviation, as given in page 73:— N. by W., S.W. ½ W., and E. by N.

EXAMINATION PAPER.—No. XIV.

FOR SECOND MATE.

1. Multiply 55 by 35, by common logarithms.

2. Divide 1858 by 63, by common logarithms.

3.—

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	S. by E. ½ E.	3	4	S.W. ½ W.	2½	A point, Cape Good Hope, in latitude 34° 28′ S., longitude 18° 28′ E., bearing by compass N. by W. ¾ W., distance 21 miles.
2		3	4			
3		3	6			
4		3	7			
5	S.W. ½ W.	3	4	W.N.W.	3	
6		3	3			
7	N.W. ½ W.	2	6	S.W by W. ½ W.	3½	
8		2	4			
9	N. by E. ½ E.	4	6	N.W. ½ W.	2¼	
10		4	4			
11		4	7			
12		4	5			
1	S.W. by W. ½ W.	5	6	N.W. ½ W.	1¾	Variation 2¼ points West.
2		5	7			
3		5	4			
4	W. by N. ½ N.	7	3	N. ½ W.	½	
5		7	5			
6		7	6			
7	N. ¾ W.	5	2	N.E. by E.	1¼	
8		4	8			
9		5	3			A current set by compass E. by N. ½ N., 14 miles from the time the departure was taken to the end of the day.
10	N.E. ½ E.	4	4	E.S.E.	2	
11	S.S.W. ½ W.	5	5	S.E. ½ S.	1½	
12		5	4			

4. 1865, February 11th, longitude 32° 20′ E., the observed meridian altitude of sun's L.L. was 30° 25′ 10″, observer North of sun, index correction — 3′ 15″, height of eye 12 feet: required the latitude.

5. In latitude 51° 10′, the departure made good was 64·3 miles: required the difference of longitude by parallel sailing.

6. Required the course and distance from A to B, by Mercator's sailing.

Latitude of A	43° 24′ S.	Longitude of A	65° 39′ W.
Latitude of B	26 38 N.	Longitude of B	15 8 E.

ADDITIONAL FOR ONLY MATE.

7. 1865, July 21st, required A.M. and P.M. tides at Dunkerque, Ipswich, and Ostend.

7*a*. 1864, April 6th, find times of high water at Cape Virgin, longitude 68° W.

7*b*. 1865, September 21st, find times of high water at A, longitude 70° W., change tide 8^h 30^m apparent time.

8. 1865, March 31st, at 6^h 1^m 48^s A.M. apparent time at ship, in latitude 6° 31′ N., longitude 155° 10′ E., the sun's magnetic amplitude was E. 3° 51′ S.: required the variation.

9. 1865, May 27th, A.M. at ship, latitude 55° N., observed altitude of sun's L.L. 43° 9′ 5″, index correction — 14″, height of eye 14 feet, time by chronometer 8^h 58^m 52^s A.M., which was *slow* 15^m 9^s for mean noon at Greenwich, April 9th, and *gaining* $5^s{\cdot}6$ daily: required the longitude.

ADDITIONAL FOR FIRST MATE.

10. 1865, September 10th, at $8^h\ 14^m\ 26^s$ A.M. mean time at ship, latitude 26° 40′ S., longitude 71° 20′ W., observed altitude of sun's L.L. 27° 26′, sun's magnetic azimuth N. 56° 17′ E., height of eye 20 feet: required the variation.

11. 1865, November 8th, P.M. at ship, latitude by account 33° 9′ N., longitude 89° 42′ E., observed altitude of sun's L.L. 40° 0′, South of observer, index correction — 6′ 12″, height of eye 19 feet, time by watch $7^d\ 20^h\ 20^m\ 20^s$, *slow* on apparent time at ship $4^h\ 8^m\ 12^s$, the difference of longitude made to *East* was 32·3 miles: required the latitude by reduction to meridian.

ADDITIONAL FOR MASTER ORDINARY.

12. 1865, July 19th, the observed meridian altitude of *α* Pavonis 32° 50′ 15″, bearing South, index correction + 4′ 48″, height of eye 23 feet: required the latitude.

EXAMINATION PAPER.—No. XV.

FOR SECOND MATE.

1. Multiply 39·8 by 81·6, by common logarithms.
2. Divide 136·58 by 7·8, by common logarithms.
3.—

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	E. ½ N.	7		N. by E. ½ E.	¾	A point, in lat. 36° 20′ S., long. 56° 45′ W., bearing by compass S.W. ¾ W., distance 15 miles.
2		6	6			
3		5	2		1¼	
4		4	6			
5	S.E.	8	2	E.N.E.	¼	
6		8	3			
7	N.E. by N.	7	4	E. by S.	½	
8		7	3			
9		7	3			
10	E. by N.	4		S. E. by S.	2	
11		3	8			
12		8	4	S.W.	0	Variation 1¼ point East.
1	E.N.E.	4	6	N.	1½	
2		4	7			
3		4	5			
4	N. by W.	6	4	N.E. by E.	¾	
5		6	3			
6		5	8			
7	N.E. by E.	5		N. by W.	1	
8		4	8			
9		4	5			A current set by compass E. by N. ½ N., at the rate of 2′·4 an hour for the last 13 hours.
10	W.N.W.	7	4	N.	¼	
11		7	4			
12		7	4			

4. 1865, November 21st, in longitude 70° 20′ E., observed meridian altitude sun's L.L. was 80° 20′ bearing North, index correction — 2′ 50″, height of eye 20 feet: required the latitude.

5. In latitude 35° 39′, the departure made good 66 miles.

6. Required the course and distance from A to B, by Mercator's sailing.

Latitude of A	6° 1′ N.	Longitude of A	60° 14′ E.
Latitude of B	6 10 S.	Longitude of B	39 15 E.

ADDITIONAL FOR ONLY MATE.

7. 1865, November 1st, find A.M. and P.M. tides at Dunbar, Dundee, and Burntisland.

7*a*. 1864, September 16th, find the times of high water at Victoria River, longitude 130° E.

7*b*. 1865, November 1st, find the time of high water at A, change tide $1^h\ 40^m$, longitude 110° E.

8. 1865, January 16th, at $7^h\ 22^m$ P.M. apparent time at ship, latitude 43° 4′ S., longitude 10° 6′ W., sun's magnetic amplitude W. 5° 56′ S.

9. 1865, June 5th, A.M. at ship, latitude 2° 5′ S., observed altitude sun's L.L. 28° 4′, index correction + 4′ 25″, eye 15 feet, time by chronometer $4^d\ 12^h\ 34^m\ 22^s$, which was $6^m\ 44^s$ *fast* for mean noon at Greenwich, March 6th, and *losing* $4^s.0$.

ADDITIONAL FOR FIRST MATE.

10. 1865, November 10th, at $8^h\ 45^m\ 38^s$ A.M., mean time at ship, latitude 50° 30′ N., longitude 86° 43′ E., observed altitude sun's L.L. 6° 7′ 10″, eye 15 feet, sun's magnetic azimuth S. 60° 30′ E.

11. 1865, January 8th, A.M. at ship, latitude account 35° 10′ S., longitude 55° 12′ W. observed altitude of sun's L.L. 76° 44′ N., index correction + 1′ 18″, eye 14 feet, time by watch $8^d\ 3^h\ 39^m\ 34^s$, which was $3^h\ 50^m\ 3^s$ *fast* on apparent time at ship, the difference of longitude made to *East* 21′.

ADDITIONAL FOR MASTER ORDINARY.

12. 1865, February 1st, longitude 50° W., observed meridian altitude of star *α* Canis Majoris *(Sirius)* 37° 50′ 20″ S., height of eye 19 feet, index correction + 1′ 4″: required the latitude.

13. Correct the following compass courses for local deviation, as given in page 73: S.E. ¾ E. and S.W. ¼ W.

EXAMINATION PAPER.—No. XVI.

FOR SECOND MATE.

1. Multiply 3740 by 750, by common logarithms.

2. Divide 4752000 by 49, by common logarithms.

3.—

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way.	Remarks, &c.
1	W.N.W.	8	6	N.	$\frac{1}{4}$	A point, in lat. 56° 27′ S.,
2		7	4		$\frac{1}{2}$	long. 68° 37′ W., bearing by
3		6	8			compass E. $\frac{3}{4}$ S., distance 15
4	W. by N.	6	5	N. by W.	$\frac{3}{4}$	miles.
5		5	6		$\frac{1}{2}$	
6		5	4			
7	S.W. by W.	5	2	N.W. by W.	$\frac{3}{4}$	
8		5	4			
9		5	3			
10	N. by E. $\frac{1}{2}$ E.	4	2	N.W. $\frac{1}{2}$ W.	$1\frac{1}{4}$	
11		3	8			
12	W.	7	3	N.	0	
1		6	4	N.N.W.	$\frac{3}{4}$	Variation 2 points East.
2	N.W.	6	4	N.N.E.	$\frac{1}{2}$	
3	N. $\frac{1}{2}$ W.	2	8	W.N.W.	$2\frac{1}{2}$	
4	S.W. $\frac{1}{2}$ W.	2	4	W.N.W.	3	
5	W.N.W.	3	3	S.W.	$2\frac{1}{4}$	
6	S.S.W.	6	8	W.	$\frac{1}{4}$	
7	N.N.W.	6	3	W.	$\frac{1}{2}$	
8		6	2			
9	S.W. by W.	6	7	N.W. by W.	$\frac{1}{4}$	A current set by compass
10	N. by W. $\frac{1}{2}$ W.	6	4	N.E. $\frac{1}{2}$ E.	$\frac{1}{2}$	S.S.W. $\frac{1}{2}$ W., 19 miles, from
11	W.N.W.	5		N.	1	the time the departure was
12		5	3		$1\frac{3}{4}$	taken to the end of the day.

4. 1866, January 1st, in longitude 167° 54′ E., the observed meridian altitude of sun's L.L. 83° 40′, zenith North of sun, index correction + 47″, height of eye 23 feet: required the latitude.

5. In latitude 60° 5′ S., longitude 179° 17′ W., a ship sails due West 96 miles: find the longitude in.

6. Required the course and distance from A to B, by Mercator's sailing.

Latitude of A	8° 57′ N.	Longitude of A	79° 31′ W.
Latitude of B	36 50 S.	Longitude of B	174 49 E.

ADDITIONAL FOR ONLY MATE.

7. 1865, March 1st, find the times of high water at Cardigan Bar and Eyemouth.

7*a*. 1864, March 1st, find the times of high water at Gibraltar (Method II).

7*b*. 1865, March 1st, required the times of high water at A, longitude 98° E., change tide $6^h\ 45^m$ P.M. apparent time (Method III).

8. 1865, November 4th, at $4^h\ 52^m\ 42^s$ A.M. apparent time at ship, latitude 46° 40′ S., longitude 8° 57′ W., sun's magnetic amplitude S.E. $\frac{1}{2}$ E.: required the variation.

9. 1865, September 1st, A.M. at ship, latitude 15° 31′ S., observed altitude sun's L.L. 15° 18′ 20″, index correction — 20″, height of eye 26 feet, time by chronometer, August $31^d\ 20^h\ 12^m\ 40^s$, *slow* $1^m\ 30^s$ on April 15th, and *gaining* $8^s.5$ daily: required the longitude.

ADDITIONAL FOR FIRST MATE.

10. 1865, June 1st, at 8^h 19^m A.M. mean time at ship, latitude 21° 10′ N., longitude 61° 30′ E., observed altitude sun's L.L. 39° 10′, index correction — 15″, height of eye 18 feet, sun's magnetic azimuth E. ¾ N.: required the true azimuth and variation.

11. 1865, April 13th, A.M. at ship, latitude account 0°, longitude 147° 10′ E., observed altitude of sun's L.L. 80° 30′, North of observer, index correction + 1′ 10″, height of eye 16 feet, time by watch 0^h 0^m 12^s, which had been found to be 11^m 1^s *fast* on apparent time at ship, difference of longitude made to *East* was 8½ miles, after the error on apparent time was determined.

ADDITIONAL FOR MASTER ORDINARY.

12. 1865, May 10th, the observed meridian altitude of α^2 Centauri was 10° 4′ 15″ (zenith North), index correction — 2′ 10″, height of eye 20 feet: required the latitude.

EXAMINATION PAPER.—No. XVII.

FOR SECOND MATE.

1. Multiply 190 by 47·5, by common logarithms.
2. Divide 8100900 by 900, by common logarithms.
3.—

H.	Courses.	K	$\frac{1}{10}$	Winds.	Lee-way	Remarks, &c.
1	N. by E. ½ E.	5	4	N.W. ½ W.	¾	A point, in lat. 34° 28′ S.,
2		6	8			long. 18° 28′ E., bearing
3	N. by E. ½ E.	7	6	N.W. ½ W.	¼	by compass N.W., dis-
4		8	3			tance 23 miles.
5	up S.W.	Drift				
6	off S.	2 knots.		W.N.W.	5½	
7		⅌ hour.				
8	up S.W. ½ W.	1½ knots		N.W.	6½	
9	off S.W. by S.	⅌ hour.				
10	up W. by S.	Do.		N.W. by N.	6½	
11	off S.W.					
12	up N. ½ E.					Variation 2½ points West.
1	off N.W. by W.	Do.		E.N.E.	7	
2						
3	up N.N.E.	1 mile				
4	off N. by W.	⅌ hour		E.	6¼	
5						
6	up N.N.W.	1½ knots		N.E.	6½	
7	off N.W. by W.	⅌ hour.				
8	N.W. by W.	6	4	N.E.	0	A current set by com-
9		6	5			pass N.W., 10 miles, from
10		7	4			the time the departure
11		8	3			was taken to the end of
12		9	2			the day.

4 1865, September 23rd, longitude 57° 45′ E., observed meridian altitude sun's L.L. 84° 10′ 50″, bearing North, index correction — 1′ 36″, height of eye 16 feet: required the latitude.

5. In latitude 52° S., longitude 0° 40′ W., a ship sails 136 miles due East: required the longitude in.

6. Required the course and distance from A to B.

Latitude of A	5° 21′ N.	Longitude of A	163° 1′ E.
Latitude of B	36 50 S.	Longitude of B	73 6 W.

ADDITIONAL FOR ONLY MATE.

7. 1865, December 1st, find A.M. and P.M. tides at Aberdeen Bar; Penzance and King's Road, Bristol Channel.

7*a*. 1864, December 29th, find times of high water at Yarmouth Roads and Southampton (Method II).

7*b*. 1865, December 31st, find time of high water at A, longitude 120° W., change tide 8^h 40^m P.M., apparent time.

8. 1865, November 5th, at 5^h 10^m P.M. apparent time at ship, in latitude 20° 45′ N., longitude 116° 45′ E., the sun's magnetic amplitude was S.W. ¾ W.: required the variation.

9. 1865, August 5th, A.M. at ship, latitude at noon 30° 30′ N., observed altitude sun's L.L. 35° 6′, height of eye 16 feet, time by chronometer 8^h 39^m 22^s P.M., *fast* 30^m 0^s on Greenwich mean noon, July 20th, and *gaining* $2^s{\cdot}3$ daily, course till noon West (true) 48 miles: required the longitude in at noon.

ADDITIONAL FOR FIRST MATE.

10. 1865, August 13th, mean time at ship, 9^h 5^m 20^s A.M., latitude 30° 46′ S., longitude 78° 50′ W., sun's bearing by compass N. 35° E., observed altitude sun's L.L. 27° 12′, index correction + 1′ 45″, height of eye 21 feet: required the true azimuth and variation.

11. 1865, June 12th, P.M. at ship, latitude account 15° 50′ S., longitude 72° 12′ E., observed altitude of sun's L.L. 50° 10′ 10″, zenith South of observer, index correction — 5′ 40″, height of eye 26 feet, time by watch 12^d 0^h 28^m 40^s, which had been found to be *slow* 4^m 44^s on apparent time at ship, the difference of longitude made to *West* was 16½ miles, after the error on apparent time was determined.

ADDITIONAL FOR MASTER ORDINARY.

12. 1865, December 7th, the observed meridian altitude of the star *a* Arietis was 60° 29′ 50″, zenith North of star, index correction — 2′ 10″, height of eye 18 feet; required the latitude.

THE ADJUSTMENTS OF THE SEXTANT.

1st. *The index-glass, or central mirror, must be perpendicular to the plane of the instrument.*

Place the index to about 60°—viz., to near the middle of the *arc* or *limb*. Hold the sextant with its face up, the index-glass being placed near the eye, and the limb turned from the observer. Look obliquely down the glass; then, if the part of the arc to the right, and its image in the mirror, appear as one *continued arc of a circle*, the adjustment is perfect; if the reflection seems to *droop* from the arc itself, the glass leans *back;* if it *rises upward,* the glass leans *forward.* The position is rectified by the screws at the back.

2nd. *The horizon-glass, or fixed mirror, must be perpendicular to the plane of the instrument.*

Set 0 on the index to 0 on the arc; hold the instrument horizontally —viz., with its *face up;* look through the sight-vane, or through the socket which receives the telescope, and direct the sight to the horizon-glass; give the instrument a small nodding motion; then, if the horizon, as seen through the transparent part of the horizon-glass, and its image, as seen in the silvered part, appear to be in a *continued straight line,* the adjustment is perfect; if the *image* be the lower, the glass stoops *forward;* if it be the *higher,* the glass leans *backward;* and the upper adjusting screw, at the back of the horizon-glass, is to be carefully turned till the coincidence of the reflected and real horizons is quite perfect.

3rd. *The horizon-glass must be parallel to the index-glass.* Set 0 on the index to 0 on the arc; screw the tube or telescope into its socket, and turn the screw at the back of the instrument till the line which separates the transparent and silvered parts of the horizon-glass appears in the middle of the tube or telescope. Hold the sextant vertically—that is with its arc or limb downwards—and direct the sight through the tube or telescope to the horizon; then, if the reflected and true horizons do not coincide, turn the tangent screw at the back of the horizon-glass till they are made to appear in the same straight line. Then will the horizon-glass be truly parallel to the index-glass.

4th. *The axis of the telescope must be parallel to the plane of the instrument.*

Turn the eye-piece of the telescope till two of the parallel wires in its focus appear parallel to the plane of the instrument; then select two objects, as the sun and moon, whose angular distance must not be *less* than from 100° to 120°, because an error is more easily discovered when

the distance is great; bring the reflected image of the sun exactly in contact with the direct image of the moon, at the wire nearest the plane of the sextant, and fix the index; then, by altering a little the position of the instrument, make the object appear on the other wire; if the contact still remains perfect, no adjustment is required; if they separate, *slacken* the screw *furthest* from the instrument in the ring which holds the telescope, and tighten the other, and *vice versâ* if they overlap.

*5th. To find the index error.**—Move the index till the horizon, or any distant object, coincide with its image, and the distance of o on the index from o on the limb is the index error; sutractive when o on the index is to the left, and additive when it is to the right of o on the limb.

Example.—The horizon and its image being made to coincide, the reading is 2′ *on* the arc. Then 2′ is the *index correction* to be *subtracted* from every angle observed.

Or measure the sun's horizontal diameter, moving the index forward on the divisions until the images of the true and reflected sun's touch at the edges; read off the measure which will be *on* the arc; then cause the images to change sides, by moving the index back; take the measure again, and read off; this reading will be *off* the arc; half the difference of the two readings is the index correction.

When the reading *on* the arc is the *greater*, the correction is *subtractive;* when the *lesser*, *additive.*

Ex. 1. On the arc —	33′ 10″	Ex. 2. On the arc —	30′ 20″
Off +	30 50	Off +	33 30
	2)2 20		2)3 10
Index corr. *sub.*	1 10	Index corr. *add*	1 35

One-fourth of the sum of the two readings should be equal to the sun's semi-diameter in the *Nautical Almanac* for the day.

Thus, suppose the observations in example 1 to be made on September 26th, 1865, here one-fourth of the sum of the two readings is 16′ 0″, agreeing with the semi-diameter as given in the Nautical Almanac for the given day.

This affords a test of the accuracy with which the observation has been made.

Note.—If both readings are *on* the arc, or both *off* the arc, half their sum is the index correction—*subtractive* when both *on*, *additive* when both *off* the arc.

* The index error of reflecting astronomical instruments, such as the sextant, is the difference between the zero (o) point of the graduated limb, and where the zero (o) point ought to be, as shown by the index, when the index-glass is parallel to the horizon-glass.

LOG LINE.

The length of the stray-line should be sufficient to allow the log-chip to be clear of the eddies of the vessel's wake.

The distance between the knots should bear the same proportion to the number of seconds run by the glass intended to be used, as the number of feet in a nautical mile bears to the number of seconds in an hour.

The number of feet in a nautical mile is 6080.

The number of seconds in an hour is 3600.

Therefore, to find the length of a knot corresponding to a 28 seconds glass, we proceed as follows:—

```
3600 : 6080 :: 28
         28
      ------
       48640
      12160
      ------ ft. in.
360,0)17024,0(47 3½
      1440
      ----
      2624
      2520
      ----
       104
        12
      ----
  360)1248(3½
      1080
      ----
```

We have for glasses running 30 seconds and 32 seconds the following proportions:—

3600 : 6080 :: 30 : 50 feet 8 inches.
3600 : 6080 :: 32 : 54 feet 0½ inch.

MARKING THE LEAD LINE.

In nautical phrase the lead line has "nine marks and eleven deeps."

At two fathoms, the mark is leather; at three fathoms, leather; at five, white rag; at seven, red rag; at ten, a piece of leather with a hole in it; at thirteen, blue rag; fifteen, white rag; seventeen the same as at seven; at twenty fathoms, a piece of cord with two knots.

Deep-sea lead lines are marked the same as far as twenty fathoms; then add a piece of cord with an additional knot for every ten fathoms, and a strip of leather for every five fathoms.

LIGHTS AND FOG SIGNALS.

THE following is the Admiralty notice respecting lights and fog signals to be carried and used by sea-going vessels, to prevent collision.—*Merchant Shipping Act Amendment Act, June 1st,* 1863.

STEAM VESSELS.—All sea-going steam-vessels, when under steam, shall, between sunset and sunrise, exhibit the following lights:—

A bright *White Light* at the foremast head.

A *Green Light* on the starboard side.

A *Red Light* on the port side.

1. The *Mast-head Light* shall be so constructed as to be visible on a dark night, with a clear atmosphere, at a distance of at least 5 miles, and shall show an uniform and unbroken light over an arc of the horizon of 20 points of the compass; and it shall be so fixed as to throw the light 10 points on each side of the ship—viz., from right ahead to 2 points abaft the beam on either side.

2. The *Green Light* on the starboard side, and the *Red Light* on the port side, shall be so constructed as to be visible on a dark night, with a clear atmosphere, at a distance of at least 2 miles, and show an uniform and unbroken light over an arc of the horizon of 10 points of the compass; and they shall be so fixed as to throw the light from right ahead to 2 points abaft the beam on the starboard and on the port sides respectively.

3. The side lights are to be fitted with inboard screens projecting at least 3 feet forward from the light, so as to prevent the lights from being seen across the bow.

4. Steam-vessels under sail only, are not to carry their *Mast-head Light.*

STEAM SHIPS when towing other ships, shall carry *Two Bright White Mast-head Lights* vertically, in addition to their side lights, so as to distinguish them from other steam ships. Each of these mast-head lights shall be of the same construction and character as the mast-head lights which other steam ships are required to carry.

SAILING SHIPS under way, or being towed, shall carry the same lights as steam ships under way, with the exception of the *White Mast-head Lights,* which they shall never carry.

Whenever, as in the case of small vessels during bad weather, the *Green* and *Red Lights* cannot be fixed, these lights shall be kept on deck, on their respective sides of the vessel, ready for instant exhibition; and shall, on the approach of or to other vessels, be exhibited on their respective sides in sufficient time to prevent collision, in such manner as

to make them most visible, and so that the *Green Light* shall not be seen on the port side, nor the *Red Light* on the starboard side. To make the use of these portable lights more certain and easy, the lanterns containing them shall each be painted outside with the colour of the light they respectively contain, and shall be provided with suitable screens.

SHIPS AT ANCHOR.—Ships, whether steam ships or sailing ships, when at anchor in roadsteads or fairways, shall exhibit, where it can best be seen, but at a height not exceeding 20 feet above the hull, a *White Light*, in a globular lantern of 8 inches in diameter, and so constructed as to show a clear, uniform, and unbroken light visible all round the horizon, and at a distance of at least 1 mile.

SAILING PILOT VESSELS shall not carry the lights required for other sailing vessels, but shall carry a *White Light* at the mast-head, visible all round the horizon,—and shall also exhibit a *Flare-up Light* every 15 minutes.

OPEN FISHING BOATS and other open boats shall not be required to carry the side lights required for other vessels; but shall, if they do not carry such lights, carry a lantern having a *Green Slide* on the one side and a *Red Slide* on the other side; and on the approach of or to other vessels, such lantern shall be exhibited in sufficient time to prevent collision, so that the *Green Light* shall not be seen on the port side, nor the *Red Light* on the starboard side.

Fishing vessels and open boats when at anchor, or attached to their nets and stationary, shall exhibit a bright *White Light;* they shall, however, not be prevented from using a *Flare-up* in addition, if considered expedient.

Fog Signals.—Whenever there is a fog, whether by day or night, the fog signals described below shall be carried and used, and shall be sounded at least every 5 minutes, viz.:—

(*a.*) Steam ships under way shall use a *Steam Whistle* placed before the funnel, not less than 8 feet from the deck.

(*b.*) Sailing ships under way shall use a *Fog Horn.*

(*c.*) Steam ships and sailing ships when not under way shall use a *Bell.*

RULE OF THE ROAD.

Two Sailing Ships meeting.—If two sailing ships are meeting end on or nearly end on so as to involve risk of collision, the helms of both shall be put to Port, so that each may pass on the Port Side of the other.

Two Sailing Ships crossing.—When two sailing ships are crossing so

as to involve risk of collision, then, if they have the wind on different sides, the ship with the wind on the Port Side shall keep out of the way of the ship with the wind on the Starboard Side; except in the case in which the ship with the wind on the Port Side is close-hauled and the other ship free, in which case the latter ship shall keep out of the way; but if they have the wind on the same side, or if one of them has the wind aft, the ship which is to windward shall keep out of the way of the ship which is to leeward.

Two Ships under Steam meeting.—If two ships under steam are meeting end on or nearly end on so as to involve risk of collision, the helms of both shall be put to Port, so that each may pass on the Port Side of the other.

Two Ships under Steam crossing.—If two ships under steam are crossing so as to involve risk of collision, the ship which has the other on her own Starboard Side shall keep out of the way of the other.

Sailing Ship and Ship under Steam.—If two ships, one of which is a sailing ship, and the other a steam ship, are proceeding in such directions as to involve risk of collision, the steam ship shall keep out of the way of the sailing ship.

Ships under Steam to slacken Speed.—Every steam ship, when approaching another ship so as to involve risk of collision, shall slacken her speed, or, if necessary, stop and reverse; and every steam ship shall, when in a Fog, go at a moderate speed.

Vessels overtaking other Vessels.—Every vessel overtaking any other vessel shall keep out of the way of the said last-mentioned vessel.

Where by the above rules one of two ships is to keep out of the way, the other shall keep her course, subject to the qualifications contained in the following article.

Proviso to save special cases.—In obeying and construing these rules, due regard must be had to all dangers of navigation; and due regard must also be had to any special circumstances which may exist in any particular case rendering a departure from the above rules necessary in order to avoid immediate danger.

No Ship under any circumstances to neglect proper precautions.—Nothing in these rules shall exonerate any Ship, or the Owner, or Master, or Crew thereof from the consequences of any neglect to carry Lights or Signals, or of any neglect to keep a proper look-out, or of the neglect of any precaution which may be required by the ordinary practice of seamen, or by the special circumstances of the case.

The diagrams and explanation on the next page (222) will assist the seaman in the practical application of the regulations.

DIAGRAMS TO ILLUSTRATE THE USE OF THE LIGHTS CARRIED BY VESSELS AT SEA,

AND THE MANNER IN WHICH THEY INDICATE TO THE VESSEL WHICH SEES THEM THE POSITION AND DESCRIPTION OF THE VESSEL THAT CARRIES THEM.

WHEN BOTH RED AND GREEN LIGHTS ARE SEEN.

A sees a Red and Green Light ahead :—**A** knows that a vessel is approaching her on a course directly opposite to her own, as **B**; (Fig. 1).

If **A** sees a White Mast-head Light above the other two, she knows that **B** is a steam vessel.

WHEN THE RED, AND NOT THE GREEN LIGHT IS SEEN.

A sees a Red Light ahead or on the bow :—**A** knows that either (Fig. 2) a vessel is approaching her on her Port bow, as **B**; or (Fig.3), a vessel is crossing in some direction to Port, as **D D D**.

If **A** sees a White Mast-head Light above the Red Light, **A** knows that the vessel is a steam-vessel, and is either approaching her in the same direction, as **B**, or is crossing to Port in some direction, as **D D D**.

WHEN THE GREEN, AND NOT THE RED LIGHT IS SEEN.

A sees a Green Light ahead or on the bow :—**A** knows that either (Fig. 4) a vessel is approaching her on her Starboard bow, as **B**; or (Fig. 5), a vessel is crossing in some direction to Starboard, as **D D D**.

If **A** sees a White Mast-head Light above the Green Light, **A** knows that the vessel is a steam-vessel, and is either approaching her in the same direction, as **B**, or is crossing to Starboard in some direction, as **D D D**.

Face p. 222.

Fig. 1

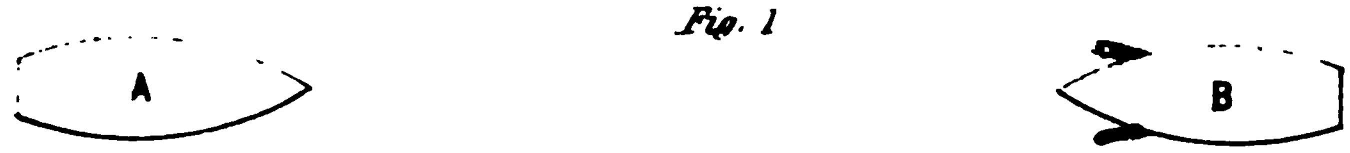


Fig. 2

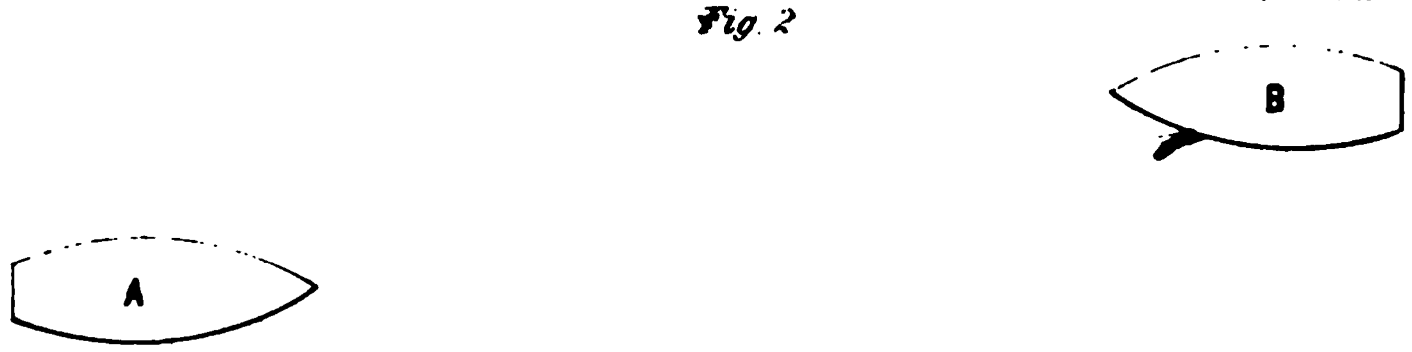


Fig. 3

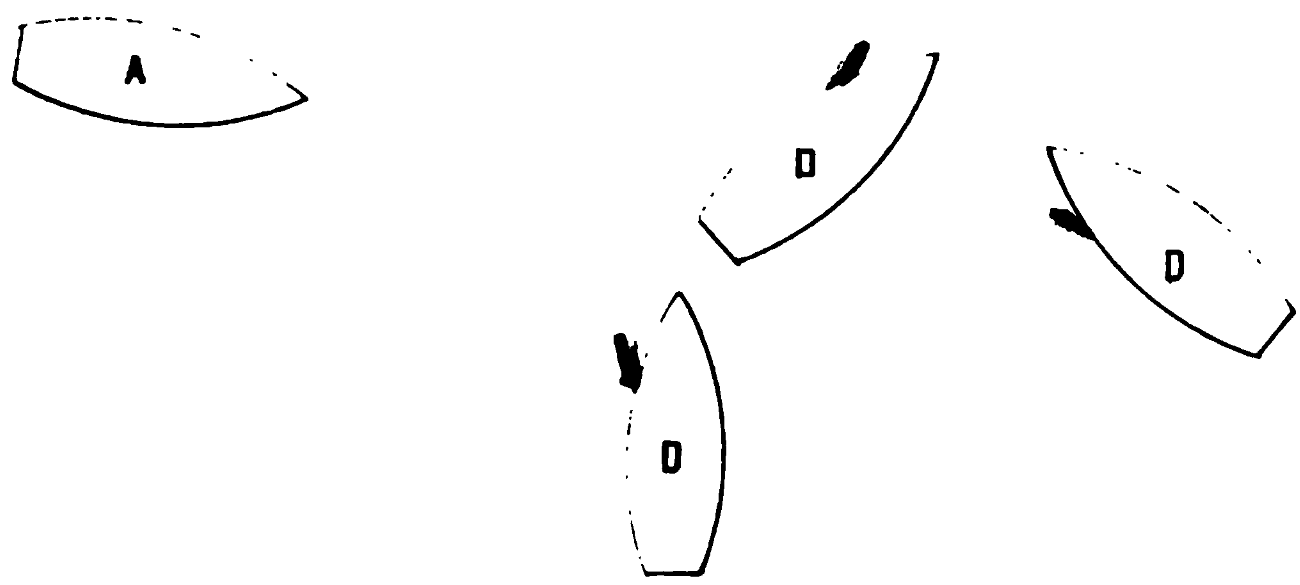


Fig. 4

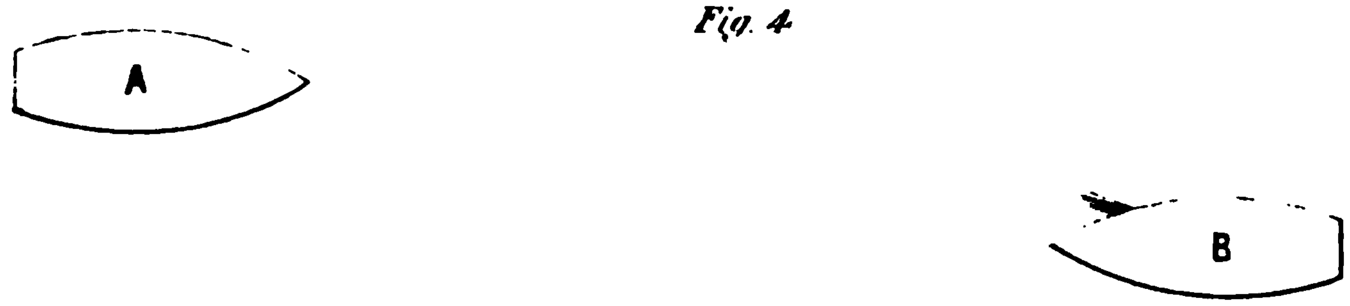
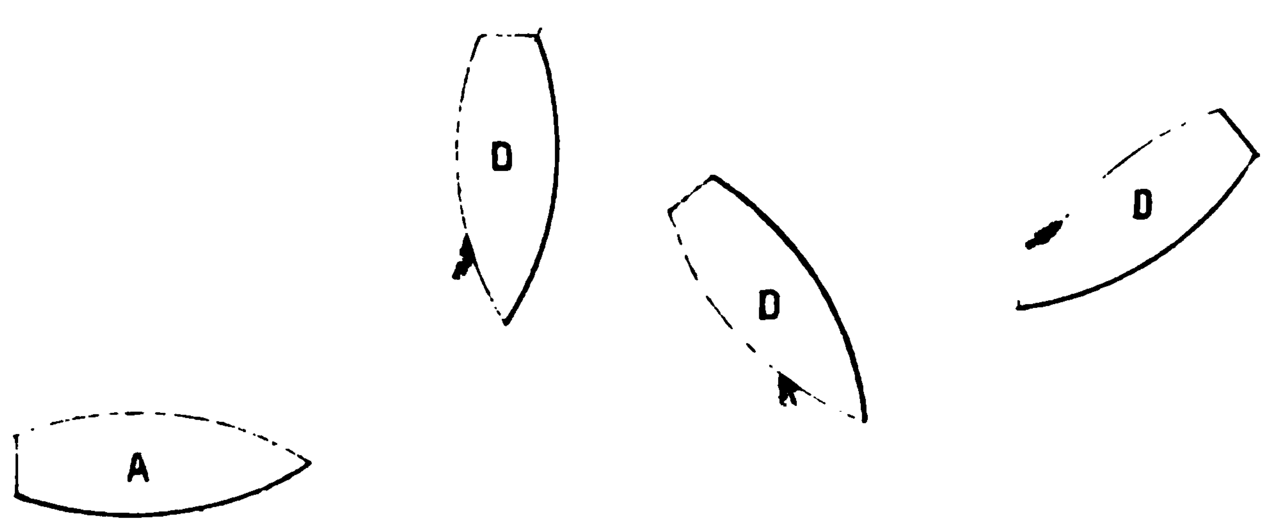


Fig. 5



ON THE CHART.

A CHART is a map or plan of a sea or coast. It is constructed for the purpose of ascertaining the position of the ship with reference to the land, and of shaping a course to any place.

The use to be made of the chart in each case determines the method of projection, and the particulars to be inserted. (1.) The chart may be required for coasting purposes, for the use of the pilot, &c., and then only a very small portion of the surface of the globe being represented at once, no practical error results from considering that surface a plane, and a "*plane chart*" is constructed in which the different headlands, lighthouses, &c., are laid down according to their bearings. The soundings on these charts are marked with great accuracy; the rocks, banks, and shoals, the channels, with their buoys, the local currents, and circumstances connected with the tides, are also noted. (2) Again, for long sea passages the seaman requires a chart on which his course may be conveniently laid down. The track of a ship always steering the same course appears as a straight line (and can at once be drawn with a ruler) on the *Mercator's chart*. Hence the charts used in navigation are Mercator's charts. (3.) When great circle sailing is practicable, and of advantage, a chart on the "*central projection*," or gnomic, exhibits the track as a straight line, and is therefore convenient.*

ON MERCATOR'S CHARTS.

(See Norie, pages 126—131; or Raper's "Practice of Navigation," pages 120—127, on this subject.)

A CHART used at sea for marking down a ship's track and for other purposes, exhibits the surface of the globe on a plane on which the meridians are drawn parallel to each other, and therefore the parts, BH, CI, DK, &c. (Fig., p. 44), arcs of parallels of latitude, are increased and become equal to the corresponding parts of the equator UV, VW, &c. Now, in order that every point of this plane may occupy the same

* The method lately introduced by Hugh Godfray, Esq., M.A., St. John's College, Cambridge, deserves special mention, as its beauty and simplicity will ultimately lead to its general adoption. A chart on the central projection, as stated above, exhibits the great circle as a straight line, and thus it is seen at once, whether the track between two places is a practicable one; hence, also, we have by inspection the point of highest latitude. An accompanying diagram then gives the different courses and distances to be run on each, in order to keep with $\frac{1}{8}$ of a point to the great circle. This chart and diagram is fully described in the *Transactions of the Cambridge Philosophical Society*, vol. X, part II; and is published by J. D. Potter, Poultry. Mr. W. C. Bergen, of Blyth, Master in the Mercantile Marine, has also published Charts on the Gnomic Projection, and claims to share with Mr. Godfray the credit of proposing the use of this projection for charts in navigation.

relative position with respect to each other that the points corresponding to them do on the surface of the globe, the distance between any points A and O, and A and F must be increased in the same proportion as the distance FO has been increased. The true difference of latitude, AO, is thus projected on the chart into what is called the *meridional difference* of latitude (see pp. 46—47), and the departure BH + CI + DK, &c., into the difference of longitude, and the representation is called a Mercator's projection. It is evidently a true representation as to *form* of every particular small tract, but varies greatly as to point of *scale* in its different regions, each portion being more and more enlarged as it lies farther from the equator, and thus giving an appearance of distortion.*

(1.) In charts generally, the upper part as the spectator holds it, is the North, and that towards his right hand, the East, as on the compass card.

(2.) On Mercator's chart the parallel lines from North to South (from top to bottom) are termed *meridians*, and they are all perpendicular to the equator, the meridians on the extreme *right* and *left* are the *graduated* meridians—so called from showing the divisions for degrees and minutes. The *latitude* is measured on the graduated meridians, and also the *distance*.

---

* It is plain from the principles of Mercator's projection, and from the diagram (page 89) which connects the enlarged meridian with the difference of longitude, that if a ship set out from any point on the globe, and sail on the same oblique rhumb towards the pole, it can reach it only after an infinite number of revolutions round it. For from any point to the pole, the projected meridian is infinite in length, and so, therefore, is the difference of longitude due to this advance in latitude upon an oblique course. Consequently, this latitude can be reached only after the ship has circulated round the pole an infinite number of times.

These endless revolutions, however, are all performed in a finite time, the entire track of the ship being of limited extent. This, however, paradoxical it may appear, is necessarily true from the principles of plane sailing, which shows that any finite advance in latitude is always connected with a finite length of track; this length being $\frac{\text{diff. lat.}}{\text{cos. course.}}$

The apparent paradox of the infinite number of revolutions about the pole being performed in a finite time, becomes explicable when we consider that, whatever be the progressive rate of the ship along its undeviating course, the times of performing the successive revolutions continually diminish as the ship approaches the pole, both the extent of circuit and the time of tracing it tending to zero, the limit actually attained at the pole itself; hence there must ultimately be an infinite number of such circuits to occupy a finite time.

When the pole is reached the direction all along preserved may still be continued; and a descending path will be described similar to that just considered, and which will conduct the ship to the opposite pole, after an infinite number of revolutions round it, as in the former case. In receding from this pole the track described will at length unite with that at first traced, the point of junction being that from which the ship originally departed. But for the strict mathematical proof of these latter circumstances the student may consult Professor Davies' curious and instructive papers on *spherical co-ordinates* in the Edinburgh Transactions, vol. XII.

(3.) The parallel lines from West to East (from left to right) are called *parallels*, and they are all parallel to the equator, the parallels at the top and bottom are *graduated* to degrees and minutes—and longitude is measured on the graduated parallel.

(4.) The numerals in harbours, bays, channels, &c., indicate *soundings reduced to low water spring tides.*

(5.) When the *true* course between two places is known, it must be remembered that *Westerly* variation is allowed to the RIGHT, and *Easterly* to the LEFT hand of the true course, in order to obtain the COMPASS COURSE.

(6.) With respect to the method of determining the ship's position by cross bearings, it may be observed that this is the most complete of all methods when the difference of bearings is near 90°; but if the difference is small—as, for example, less than 10° or 20°, or near 180°—the ship's position will be uncertain, because a small error in the bearing will cause a great error in the distance.—(Raper, page 120, No. 367.)

EXERCISES ON THE CHART.

FOR ONLY AND FIRST MATES.

North Sea.

(1.) Latitude 55° 5′ N.
Longitude 0 5 E.

Required the course and distance to Hartlepool.

(2.) Latitude 55° 30′ N.
Longitude 3 15 E.

Required the course and distance to Brouwershaven.

(3.) Latitude 57° 30′ N.
Longitude 0 40 E.

Required the course and distance to Tynemouth Light.

(4.) Latitude 57° 25′ N.
Longitude 7 25 E.

Required the course and distance to the Naze of Norway.

(5.) Latitude 53° 35′ N.
Longitude 0 55 E.

Required the course and distance to the Dudgeon Light.

(6.) Latitude 55° 28′ N.
Longitude 0 30 W.

Required the course and distance to Tynemouth Light.

(7.) Latitude 55° 10′ N.
Longitude 0 35 E.

Required the course and distance to Flambro' Head.

(8.) Latitude 54° 30′ N.
Longitude 2 15 E.

Required the course and distance to the Outer Dowsing Light.

(9.) Latitude 60° 21′ N.
Longitude 0 35 E.

Required the course and distance to Udsire.

(10.) Latitude 58° 50′ N.
Longitude 4 33 E.

Required the course and distance to Sundevoieg.

English and Bristol Channels, and South Coast of Ireland.

(1.) Latitude 50° 1′ N.
Longitude 2 4 W.

Required the compass course and distance to the Caskets.

(2.) Latitude 49° 55′ N.
Longitude 0 45 W.

Required the compass course and distance to Fecamp.

(3.) Latitude 49° 30′ N.
Longitude 3 30 W.

Required the compass course and distance to the Start Point.

(4.) Latitude 48° 50′ N.
Longitude 5 50 W.

Required the compass course and distance to Ushant.

(5.) Latitude 49° 40′ N.
Longitude 0 45 W.

Required the compass course and distance to Ushant.

(6.) Latitude 50° 10′ N.
Longitude 1 10 W.

Required the compass course and distance to St. Catherine's Light.

(7.) Latitude 50° 30′ N.
Longitude 0 55 E.

Required the compass course and distance to Dungeness.

(8.) Latitude 48° 55′ N.
Longitude 6 5 W.

Required the compass course and distance to the Lizard.

(9.) Latitude 50° 10′ N.
Longitude 3 10 W.

Required the compass course and distance to Portland.

(10.) Latitude 49° 55′ N.
Longitude 3 55 W.

Required the compass course and distance to the Eddystone.

(11.) Latitude 50° 50′ N.
Longitude 10 35 W.

Required the compass course and distance to the Fastnet Rock.

(12.) Latitude 50° 55′ N.
Longitude 6 55 W.

Required the compass course and distance to Trevose Head.

(13.) Latitude 50° 50′ N.
Longitude 7 20 W.

Required the compass course and distance to Old Head of Kinsale.

(14.) Latitude 50° 30′ N.
Longitude 8 30 W.

Required the compass course and distance to Cape Clear.

(15.) Latitude 50° 40′ N.
Longitude 6 30 W.

Required the compass course and distance to Lundy Island.

(16.) Latitude 51° 28′ N.
Longitude 6 30 W.

Required the compass course and distance to the Smalls Rock.

ORDINARY MASTER.

North Sea.

(1.) Sunderland Light, bearing by compass S.W. ½ S.
Coquet Island, „ „ N.W.

Required the latitude and longitude of ship; also the course and distance to Hartlepool Light.

(2.) Buchanness Light, N. by W. ½ W., by compass
Girdleness Light, West, „

Required the latitude and longitude of ship; also the course (by compass) and distance to the Staples.

(3.) The Skerries, North, by compass.
Sumburgh Head, W. ¼ S., „

Required the latitude and longitude in; also the compass course and distance to Peterhead.

(4.) The Dudgeon Light, W. by N., by compass.
Hasbro' Sand-end Light, S.S.W., „

Required the latitude and longitude of ship; also the compass course and distance to Flambro' Head.

English and Bristol Channels, and South Coast of Ireland.

(1.) Longships Light, bearing by compass E.N.E.
St. Agnes' Light, „ „ N.N.W. ½ W.

Required the latitude and longitude in; also the compass course and distance to the Lizard.

(2.) Cape Barfleur, bearing by compass N.W.
St. Marcouf, „ „ S.W.

Required the latitude and longitude of ship; also the compass course and distance to Cape de la Heve.

(3.) Bembridge Light Vessel, bearing by compass N. ½ W.
Owers Light Vessel, „ „ East.

Required the latitude and longitude of ship; also the compass course and distance to St. Catherine's Point.

(4.) Needles Light, bearing by compass N. ¼ E.
St. Catherine's Light, „ „ E. ¾ S.

Required the latitude and longitude of ship; also the compass course and distance to St. Alban's Head.

(5.) Caldy Island Light, bearing by compass E.N.E.
Lundy Island Light, „ „ S. by E.

Required the latitude and longitude of ship; also the compass course and distance to the Smalls.

(6.) Lizard Lights, bearing by compass E. ½ S.
Longships, „ „ N. ¼ W.

Required the latitude and longitude of ship; also the compass course and distance to St. Agnes' Light.

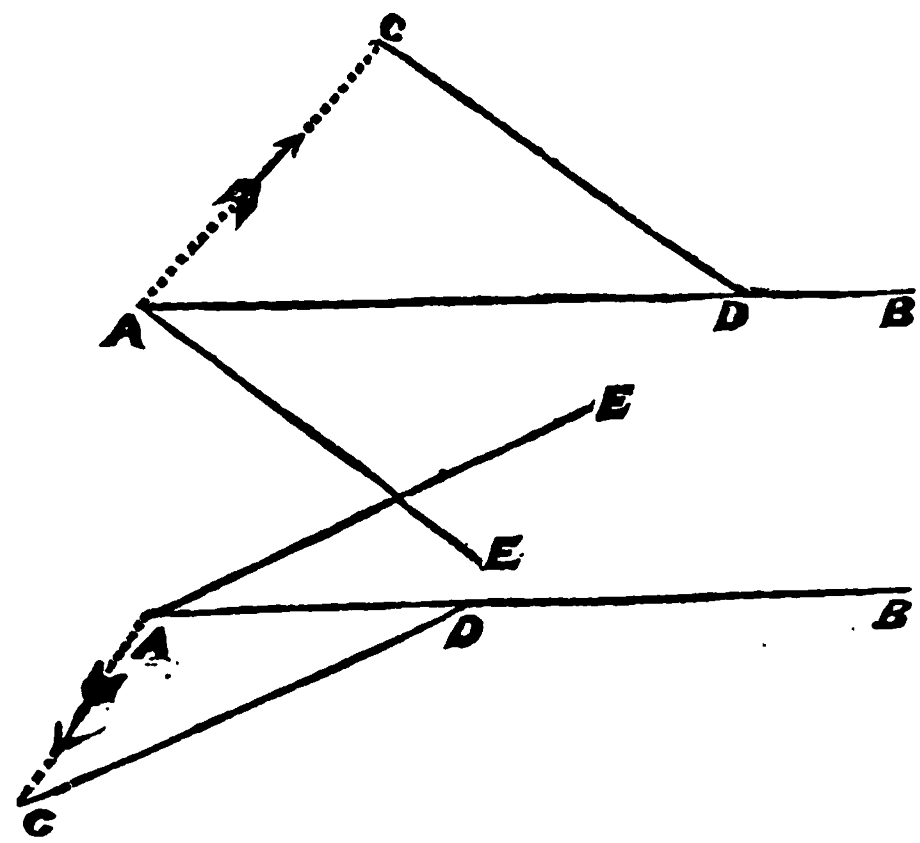
(7.) Mine Head Light, bearing by compass N.E. ¾ N.
Ballycotton Light, „ „ N.W.

Required the latitude and longitude of ship; also the compass course and distance to Old Head of Kinsale.

TO FIND THE COURSE TO STEER IN ORDER TO MAKE GOOD ANY COURSE IN A KNOWN CURRENT, AND ALSO THE DISTANCE MADE GOOD.

Draw a line on a chart to represent the course to be made good; from the ship's place on the chart lay off a line in the direction of the set of the current, on which mark off from the ship's place the rate of the current per hour; then take in the compasses the distance the ship sails in an hour by log, and put one foot on the last-named mark, and from the point where the other foot reaches the first line draw a line to the mark on the line representing the direction of the current. The

course to be steered is represented by the line last drawn, and the parallel ruler being placed to it, and moved to the centre of the compass on the chart, will give the course of the ship; and that portion of the first line drawn, intersected by the last line drawn, will be the distance the ship will make good per hour.



On a chart, suppose A to be the place of the ship, B the port of destination; also A C the set of the current, the rate per hour being taken from the scale of miles and laid off in the direction of the line. Take the distance sailed by the ship per hour from the scale of miles, and with one foot of the dividers at C, make an arc cutting A at D. Join C D, and move the parallel ruler from C D to A, drawing A E parallel to C D: then A E will be the direction of the ship's head. And the parallel ruler being moved to the centre of the compass on the chart, will give the course of the ship on the chart; and A D will be the distance the ship will make good.

SOUNDINGS.

In the open sea, the tides require about six hours and a quarter to rise from low to high water, and an equal interval to fall from high to low water. If the rise or fall was an uniform quantity throughout, by simply taking a proportionate part of the rise or fall due to the time of tide, we should at once obtain the quantity required to reduce the soundings to the low water of that day. But the water does not rise

in equal proportions, the rise during the first and last hours being very small (about one sixteenth of the whole range): in the second hour there is a considerable increase of rise; in the third and fourth hours a still greater increase of rise; and then the rise begins to take off in the same proportions as it increased.*

The correct amount for every half-hour, and for various ranges, is given in the "Tide Tables for the English and Irish Ports for 1864," (p. 98, Table B) published by the Hydrographic Office, Admiralty.

As the soundings upon the charts are all referred to *low* water of *ordinary* spring tides,† casts of the lead taken at any other time of the tide, or any other day than full and change, will exceed the depth marked on the chart (except when it happens to be low water of *greatest* spring tides). It is necessary for the seaman to be able to calculate the difference between the actual depth obtained by means of his lead, and that marked on his chart, in order to the identification of his ship's place, more especially when the range of tide is considerable, and the depth not great. Also, when about to enter a port in a vessel whose draught of water is nearly equal to the depth, it is necessary to find the height of tide as exactly as circumstances will permit.

Two classes of questions may be proposed in reference to this subject—*firstly*, to find the depth of water at a given place and time; *secondly*, having obtained the actual depth by a cast of the lead, to find the sounding on the chart corresponding thereto, and thence to identify the ship's place. Both these classes of questions require us to know the *time* of high water and the *range* of the tide on the given day; and for this purpose almanacs are published. The most correct, and by far the most useful of all these, are the "Tide Tables" published by

* The reader may obtain an idea of this law, sufficiently exact for practical purposes, in the following manner:—Describe a circle, and divide the circumference into six equal parts on each side, corresponding to the hours of the tide; then divide the diameter into proportional parts, corresponding to a given (assumed) range of tide. Connect the segments of the circle by straight lines drawn across the figure, when it will be perceived that they intersect the diameter at certain divisions of the range. These are the correct quantities respectively due to each hour's rise or fall of such a tide from low to high water, and *vice versâ*. An examination of these quantities will show, that in the first hour of the tide the rise is equal to one-sixteenth of the whole range; at two hours from low or high water, the tide has risen or fallen *one-fourth* of the whole range: at three hours, it has risen just *half* its range; at four hours, it has risen *three-fourths* of the whole range; at five hours, to within a *sixteenth* of the whole range. The above method, which is constructed upon principles theoretically correct, will represent with sufficient exactness all that is necessary for practical purposes.

† On most charts the soundings expressed are reduced to low water of *ordinary spring tides;* but in some charts, however, the soundings are reduced to the low water of extraordinary spring tides—such, for example, is the case on the chart of Liverpool, surveyed by Captain Denham, R.N., the soundings on which are reduced to a spring range of thirty feet, while the mean spring range for that place, as deduced from observations made for two years at the Tide Gauge, St. George's Pier, is 26 feet

the Admiralty, and to which we have already referred. In this book are given the times of *high water* and the *height of the tide* for every day in the year, at each of the principle ports in Great Britain.

We propose commencing our examples by some questions illustrative of the *time* and *range* of tide.

To find the time of tide, we proceed according to

RULE LXII.

1°. *Open the* Admiralty Tide Tables *at the proper month; and in the column under the head of the place near your position, and opposite the day of the month, take out the "time" of high water in the morning or afternoon, as the case requires, and write it down.*

2°. *Next place underneath the time at ship, and take the* difference, *and call it* "time from high water."

Examples.

Ex. 1. 1864, May 12th, at 5^h P.M.: required the interval from high water at Belfast.

Time of high water, Belfast (page 40, *Admiralty Tide Tables*) ..	3^h 3^m P.M.
Subtract from time at place	5 0
Time *after* high water ..	1 57

Ex. 2. 1864, May 7th, at 8^h 36^m P.M.: find the interval from high water at North Shields.

Time of high water, North Shields (page 37, *Admiralty Tide Tables*)	10^h 1^m
Subtract from time at place	8 36
Time *before* high water ..	1 25

To find the Range of Tide for the given day, proceed according to

RULE LXIII.

1°. *Enter the* Admiralty Tide Tables *at the proper month; and in the column under the head of the place, and under height, take out the figures which stand opposite the day.*

2°. *From this subtract the half mean spring range, which stands at the foot of the column.*

The remainder is the *half-range* of the day.

Examples.

Ex. 1. 1864, April 3rd: find the range of the morning tide at Thurso.

	ft.	in.
Height of tide at Thurso (page 29) ..	10	10
Half mean spring range	6	7
Half-range of the day ..	4	3
		2
Range	8	6

Ex. 2. 1864, January 10th: find the half-range of the afternoon tide at London.

		ft.	in.
Height at London (page 3)	.. ..	19	7
Half mean spring range ..	.. ..	9	7
Half-range of the day	..	10	0

Examples for Practice.

Ex. 1. 1864, October 16th: find the half-range of the morning tide at Holyhead.
Ex. 2. 1864, May 11th: find the half-range of the morning tide at Liverpool.
Ex. 3. 1864, March 10th: find the range of the afternoon tide at Dover.

To find how much we must subtract from casts of the lead, in order to a comparison with the soundings marked on the chart, proceed by

RULE LXIV.

1°. *Find the time from high water* (less than 6^h), *before or after, according to* Rule LXII.

2°. *Next find the half-range for the given day,* Rule LXIII.

3°. *Enter* Table B, page 98, Admiralty Tide Tables; *and under the time from high water, and opposite the half-range for the given day, take out the correction corresponding thereto, observing whether it is to be* added *or* subtracted.

4°. Add *or* subtract *the correction, as directed, to the half spring range marked on the chart.*

The result is the correction to be made to the sounding.

Examples.

Ex. 1. 1864, September 14th, at $7^h\ 58^m$ P.M., a ship off Liverpool strikes soundings in 8 fathoms: required the corrected sounding to compare with the chart. (The half spring range by Captain Denham's chart is 15 feet.)

Admiralty Tide Tables (page 70): time of high water at Liverpool, September 14th, 1864	$9^h\ 58^m$ P.M.	
Time of sounding	7 58	
Time from high water..	2 0	
	ft.	in.
Height at Liverpool..	26	4
Half mean spring range	13	0
Half-range of the day	13	4
In Table B, page 98, under 2^h, opposite $13\frac{1}{4}$ feet, stands *add*	6	8
Half spring range by chart	15	0
Correction $3\frac{1}{2}$ fathoms, or	21	8

Depth by lead	8 fathoms.
Correction	$3\frac{1}{2}$ „
Showing the depth by comparison	$4\frac{1}{2}$ „

Whence the depth to compare with the chart is only $4\frac{1}{2}$ fathoms, instead of 8 fathoms.

Ex. 2. 1864, September 7th, at $3^h\ 39^m$ A.M., a vessel has to cross the Victoria Bar, Liverpool: it is required to know what water she will have over the Bar. (Depth at low water springs on chart, 11 feet.)

By Admiralty Tide Table: September 20th, time from high water, found as in Ex. 1.	2^h	0^m
	ft.	in.
Half-range for the day (Rule LXIII)	13	2
By Table B: with these quantities the correction is *add* ..	6	7
Half spring range by chart	13	0
Add for Liverpool chart	2	0
Correction ..	21	7
By chart: depth on Victoria Bar at low water springs ..	11	0
Depth on Bar at 2^h from high water, Sept. 20th, ...	32	7

or $5\frac{1}{2}$ fathoms, nearly.

Ex. 3. 1864, August 20th, at $8^h 38^m$ P.M., a vessel anchored off Weston-super-Mare, in $6\frac{1}{2}$ fathoms; at low water the vessel was "high and dry:" required the cause of this. (Half spring range by chart 23 feet.)

By Tables: August 20th, time of high water at Weston-super-Mare	$8^h\ 55^m$ P.M.	
Time of anchoring..	8 38	
Time before high water	0 17	
	ft.	in.
Height of tide by Tables	40	0
Half spring range	18	7
Half-range	21	5
By Table B, 17^m and half-range $21\frac{1}{2}$ give .. .. *add*	21	2
By chart: half spring range	23	0
Correction to low water	44	2
Soundings $6\frac{1}{2}$ fathoms, or	39	0
	5	2

Water below the sounding; or, the ship is found to be 5 feet dry at low water.

Examples for Practice.

Ex. 1. 1864, June 24th, at $11^h\ 22^m$ A.M: required the depth of water on the "Four-fathom Ledge" off Weston-super-Mare.

Ex. 2. 1864, August 1st, at $8^h\ 39^m$ A.M.: required the depth of water at the Fairway Buoy in the Old Formby Channel. (Admiralty Sounding, $2\frac{1}{4}$ fathoms.)

Ex. 3. 1864, June 20th, at $2^h\ 25^m$ P.M., a vessel having to cross the Victoria Bar, Liverpool: required the depth of water at that time.

Ex. 4. 1864, March 11th, at $8^h\ 34^m$ A.M., a vessel anchored off Weston-super-Mare, in $6\frac{1}{2}$ fathoms: required the depth at low water.

LLOYD'S RULES

FOR THE STOWAGE OF MIXED CARGOES,

Prepared by HENRY C. CHAPMAN & Co., *Agents for Lloyd's, Liverpool.*

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1. Owners, Commanders, and Mates of ships, are considered in law in the same situation as common carriers, it is therefore necessary that all due precautions be taken to receive and stow cargoes in good order, and deliver the same in like good order. The law holds the shipowner liable for the safe custody of the goods when properly and legally received on board in good order, and for the "delivery" to parties producing the bill of lading. The captain's blank bill of lading should be receipted by the warehouse keeper, or person authorised to receive the contents. Goods are not unfrequently sent alongside in a damaged state, and letters of indemnity given to the captain by the shippers for signing in good order and condition; this is nothing more or less than conniving at fraud; fine goods are also often damaged in the ship's hold by lumpers, if permitted to use cotton hooks in handling bales. All goods must be received on board according to the custom of the port where the cargo is to be taken in; and the same custom will regulate the commencement of the responsibility of the master and owners.

2. Hemp, flax, wool, and cotton, should be dunnaged 9 inches on the floors, and to the *upper part* of the bilge, the wing bales of the second tier kept 6 inches off the side at the lower corner, and 2½ inches at the sides. Sand or damp gravel ballast to be covered with boards. Pumps to be frequently sounded and attended to. *Sharp bottomed ships one-third less dunnage in floor and bilges.* Avoid horn shavings as dunnage from Calcutta.

3. Oil, wine, spirits, beer, molasses, tar, &c., to be stowed bung up; to have good *cross beds* at the quarters *(and not to trust to hanging beds)*, to be well chocked with wood, and allowed to stow 3 heights of pipes or butts, 4 heights of puncheons, and 6 heights of hogsheads or half-puncheons. All moist goods and liquids, such as salted hides, bales of bacon, butter, lard, grease, castor-oil, &c., should not be stowed too near "dry goods," whose nature is to absorb moisture. Shipowners have often to pay heavy damages for leakage in casks of molasses, arising from stowing too many heights without an intervening platform or 'twixt decks. From Bengal, goods also are frequently damaged by castor-oil.

4. Tea and flour, in barrels; flax, clover, and linseed, or rice, in tierces; coffee and cocoa, in bags, should always have 9 inches, at least, of good dunnage in the bottom, and 14 to the upper part of the bilges, with 2½ inches at the sides: allowed to stow 6 heights of tierces, and 8 heights of barrels. All ships above 600 tons should have 'twixt decks or platforms laid for these cargoes to ease the pressure—caulked 'twixt decks should have scuppers in the sides, and 2½ inches of dunnage laid athwartship, and not fore-and-aft ways, when in bags or sacks: and when in boxes or casks not less than 1 inch. Rice, from Calcutta, is not unfrequently damaged by indigo, for want of care in stowing.

5. Entire cargoes of sugar, saltpetre, and guano, in bags, must have the dunnage carefully attended to, as laid down for other goods. Timber ships are better without 'twixt decks if loading all timber or deals. Brown sugar to be kept separate from white sugar, and both kept from direct contact with saltpetre.

6. Pot and pearl-ashes, tobacco, bark, indigo, madders, gum, &c., whether in casks, cases, or bales, to be dunnaged in the bottom, and to the upper part of the bilges, at *least* 9 inches, and 2½ inches at the sides.

7. Miscellaneous goods, such as boxes of cheese, kegs and tubs of lard, or other small or slight-made packages, not intended for broken stowage, should be stowed by themselves, and dunnaged as other goods.

8. Barrels of provisions and tallow casks, allowed to stow 6 heights. All metals should be stowed under, and separated from, goods liable to be damaged by contact.

9. All manufactured goods, also dry hides, bales of silk, or other valuable articles, should have 2½ inches of dunnage against the side, to preserve a water-course. Bundles of sheet-iron, rods, pigs of copper or iron, or any rough hard substance, should not be allowed to come in contact with bales or bags, or any soft packages liable to be chafed. When mats can be procured, they should be used at the sides for silk, tea, &c.

10. Tar, turpentine, rosin, &c., to have flat beds of wood under the quarters, of an inch thick, and allowed to stow 6 heights.

11. Very frequent and serious loss falls on Merchants on the upper part of cargoes, particularly in vessels that bring wheat, corn, tobacco, oil-cake, &c., arising from vapour damage imbibed by wheat, flour, or other goods, stowed in the same vessel with turpentine, or other strong-scented articles: the shippers are to blame for such negligence, for not making due inquiry before shipping.

12. Ships laden with full cargoes of coal, bound round Cape Horn or Cape of Good Hope, to be provided with approved ventilators, as a preventive against ignition.

NOTE.—Shippers abroad, when they know that their cargoes will be stowed properly, will give a preference, and at higher rates, to such commanders of ships as will undertake to guarantee the dunnage. The American shipowners, in the stowage of mixed cargoes in large ships, have, from experience, discovered what "pressure" flour barrels, provision casks, &c., will bear, and so avoid reclamations for damage if otherwise properly stowed: hence, in large ships above 600 tons, with dimensions exceeding in length 4½ times the beam, and 21 feet depth of hold, orlop decks will come into general use, so as to relieve the pressure, by dividing a ship's hold like a warehouse, into stories. A large ship, called the "Liverpool," which left New York in December last, with an entire cargo of flour, has never since been heard of; it is supposed the lower tier of barrels gave way under the pressure, and the cargo having got loose, shifted in a gale of wind, and capsized the vessel. Ship's cargoes, for Insurance, will also become a matter of special agreement between merchant and shipowner, and merchant underwriters, and the premiums vary according to the dunnage agreement. The stowage and dunnage must stand A1, and is often of more importance than the class of the vessel, as experience has proved. When ships are chartered for a lump sum, the draft of water should be limited, as it not unfrequently happens that brokers insert a clause that coals are not to be considered as dead weight, in order to fill the ship up in case of goods falling short, to make up the chartered freight. All packages, bales, and cases, not weighing more than 25 cwt. to the cubic ton measurement, are designated as light freight.—*Lloyd's, May*, 1851.

MONTREAL, ETC.,—STOWAGE OF GRAIN CARGOES.

Lloyd's instructions to Masters and Mates.

1. No ship exceeding 400 tons register can be entirely loaded with grain in bulk; and all exceeding 400 tons register may take two-thirds of the cargo of grain in bulk, and one-third in bags, or rolling freight instead thereof. In the latter case, the grain in bulk should be stowed 6 inches, but not more above the beams, to allow for settling.

2. When ships take wheat, corn, &c., in bulk, it must be stowed in sections or "bins" (not to contain more than 12,000 bushells each), to be lined with thoroughly seasoned boards, grain tight, not less than 10 inches from the flat of the floor, and from 14 to 16 inches in the bilges graduated to the sides, which must be clapboard lined to the deck. Care must be taken to preserve a water-course under the lining. Good shifting boards, secured to the stanchions, extending at least 6 feet downwards and fitted tight to the deck. The stanchions not to be removed, but firmly secured. No loose grain to be stowed in the extreme ends, and no admixture of other goods. Pumps and masts cased and covered with mats and canvas, made thoroughly grain tight, with sufficient space in the well to admit the passage of a man to the heels of the pumps, and access had to the same by means of a man-hole from the deck, or by a clear passage from the 'tween decks aft. Mats to be used for covering knees, keelsons, and stanchions, if required, but not for lining or covering the sides.

3. Grain, when stowed in bags, must be dunnaged not less than 10

inches on the floor, 14 to 16 inches on the bilges, 3 inches on sides up to the deck; between decks the dunnage must be laid athwartships, at least 2 inches from the deck. Shifting plank extending at least 4 feet from deck beams downwards, secured to stanchions. The dunnage in the hold must be entirely covered with boards and sails, or mats, grain tight.

4. All bulk or loose grain must be taken in bins prepared for that purpose.

5. For dunnaging, deals are preferable to anything else. They should be laid fore-and-aft, about 3 inches apart, the second tier over the spaces of the first tier, the third tier over the spaces of the second, and so on. Staves or other materials generally used for dunnage to be placed so as to give free course for the water to reach the pumps. The dunnage should be raised from 10 to 12 inches from the floor, and in the bilges from 14 to 16 inches, according to the build of the ship and the discretion of the Inspector. Flat-floored, wall-sided ships should be fitted with bilge pumps.

6. The studs for the bulkheads should be made of three-inch deals, placed about 2 feet apart, and firmly secured at the top and bottom, and properly braced and cleeted on the lining and to the beams (or deck), to resist the pressure of the grain.

7. The studs for the bulkheads forward, and after bulkheads for ships not exceeding 10 feet depth of hold, must be 4 by 6 inches in size, and of 1 entire piece; of a greater depth than 16 feet, they must be 4 by 8 inches. They must be set 20 inches apart from centre to centre, firmly secured at the top and bottom, and properly braced and cleeted on the ceiling and deck, to resist the pressure of the grain.

8. The sides above the turn of the bilge must be lined on one-inch battens after the manner of clapboarding.

9. Shifting planks 2 inches thick must extend to the deck on each side of the stanchions, fitted tight under and between the beams and carlins, and extending not less than 6 feet downwards; care must be taken that the stanchions are well secured at both ends. In no case can single boards be substituted for plank, and the shifting boards must be shored from sides, midway between the stanchions.

10. Materials for bins must be perfectly seasoned; unseasoned lumber must not be used where it will come in contact with the grain. Water-tanks, whether of wood or iron, must be cased with wood to prevent damage from sweat or leakage. And all ships with grain in bulk ought to have feeders and ventilators.

11. It must be seen that the grain is well trimmed up between the beams, and the space between the beams completely filled.

12. When ships are chartered, the draught of water should be limited, and provision made for loading under inspection.

13. The load draught must be regulated by the depth of the hold, allowing 3 inches to every foot depth of hold, measured from lowest line of sheer of deck amidships to the water, when upright. Ships having an additional deck put on after construction, the depth of hold to be measured from original deck.

Ships loading grain complying strictly with the above rules, lined and loaded under the supervision of the surveyor appointed by Lloyd's agent, will be entitled to a certificate to that effect.

Applications for supervision will have to be made in writing, and a fee of 10 dollars charged for such supervision and certificate.

In preparing the ship's hold to receive cargo, all the limber boards are to be taken up, all dirt removed from the floors as high as can be reached, and the limber holes effectually cleared.

All perishable goods require dunnage; the quantity required for the different cargoes is indicated under their proper headings. As a general rule, however, there must not be less than 6 inches in the bottom, and 9 inches in the bilge. Dunnage is chiefly required about the pum-well and bilges, masts, in the wake of the chain-plates and transoms; since, when a ship lies along she will have most water in the wake of the floor timbers, and ships are apt to strain in the wake of the chains, owing to the weight of the masts and rigging when she lies along. The 'tween deck dunnage to be laid athwartship, and the first or ground tier not to be carried too far over towards the bilge. The bilge dunnage should always be carried well up.

In stowing the hold, homeward, from India,* the dunnage should be levelled from about 2 inches above the keelson, before the main hatch, and lowered towards the wings, to allow for the droop of the beams. The ground should not be carried too far over towards the bilge, where there should never be less than 9 inches dunnage from the skin. If the dead weight consists of cargo in bags, in stowing the third height the dunnage may be reduced to 6 inches, and above that gradually to 2 inches from the ship's side, which will be sufficient in a tight ship, excepting in the wake of the chain-plates and bolts, where it should not be less than 3 inches.

When putting dry cargo on moist, or putting one against the other, let double mats intervene. Mat in the way of iron knees and iron stanchions; dunnage and mat round masts.

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* *The Sea Officer's Manual.* By Capt. A. Parish.

Plenty of quoins should be used in stowing casks, which are to be placed bung up, bilge free, and exactly fore-and-aft, upper tiers, bilge, and cuntlines. The bilges should be free, not only from underneath, but from the casks also on either side; they may be stowed close, until the longer is completed, and then wedged off by driving quoins on each upper quarter. If the casks are not exactly in a fore-and-aft line, the chimes will lock and get broken, in breaking them out of their place. The space between casks should be filled up just high enough for the beds to rest upon, that the strain from the upper heights may not fall entirely upon the lower casks.

All cases should be stowed mark up, and entered in the hold-book as stowed.

Iron, Bar and Railway.—Bar iron should be crossed, and the crossings kept exactly one over another—the first precaution being to keep the centre of gravity up, and thereby prevent the violent rolling of the ship; and the second, to prevent the bars from working. The ceiling of the vessel should also be protected from the chafe of the ends of the bars, by putting about 3 rows of them, with their ends properly shifted, between the ceiling and the crossed bars.

An experienced stevadore recommends faggots, about 18 inches thick, to be laid athwartships from the keelson to the sides. The iron is to be placed fore-and-aft, solid or close together. Next tier to be placed angle-fashion, towards the keelson and the wings, pigeon-coated—that is, with a space of 4 inches from bar to bar. Cross the third tier the opposite way, so as to form a diamond in the openings. Then stow fore-and-aft, solid, and so continue stowing, 2 tiers open and 1 solid, until three-fifths of the cargo is in, finishing with a solid tier. On this lay dunnage as below, and then stow 1 tier solid and 2 tiers open, until the cargo is complete.

Lead.—When pig-lead only is taken, dunnage with coal and rubble until the keelson is completely covered, in order to raise the lead and make the ship easy in a sea-way. Lay plank, and stow in the middle in stacks, placing the pigs 3 or 4 inches apart, and crossing at the same distance.

Machinery.—Place it in the vessel before taking any other part of the cargo, on account of its great weight, and to afford the opportunity of securing the several pieces properly by beds and chocks. Articles such as cog-wheels, and castings of a similar shape, should be lashed vertically or edgeways to the masts, taking proper care to chock them on each side with rough cases of goods, well dunnaged.

Bale Goods.—In stowing bale goods, care should be taken to put the bales on their *flats* in midships, and on their *edges* in the wings,

that in the event of leak from the deck, 1 or 2 of the pieces only might be wet, and not the whole bale.

General Cargo.—The strongest casks—such as beer, tallow, &c.,—should be selected for the ground tier, and not dry goods, if it can be avoided,—reserving wines, spirits, oils, molasses, for second or third tier, in order to reduce the pressure. Special attention must be directed to the preventing of dry goods in bags or bales being placed near other goods liable to leakage, or moist goods—as for example, salted hides, grease, lard, bales of bacon, &c.; if possible, stow dry goods in the after hold.

Guano requires a dunnage of from 12 to 15 inches, and some even recommend 2 feet, as it tends to make the cargo more secure, and the ship easier in a sea-way. It has been recommended to stow guano on a platform similar to that used when taking in copper ore, or it should be well dunnaged, as high up as the keelson; then place bags—say 2 tiers—fore-and-aft, so as to prevent any air from being drawn through by the suction of the pumps, or the powder or loose guano from finding its way between. Dunnage the ship's sides not less than 3 inches, and carry a tier of bags up as high as the lower beams; the hold must be so stowed that a man can go on and around the cargo daily to inspect it.

Ores.—Heavy cargoes, such as copper ore, iron ore, or lead, should be conveyed in vessels having a platform built at about a fourth of her depth from the bottom; this will cause the vessel to be lively in a sea-way. Copper ore, from South America, is stowed in cases or trunks shored up in the centre. With an entire cargo a trunk way is built up in the hold, otherwise the ship will be considered not sea-worthy.

Acids, &c., must be stowed on deck, and on no account below, but in such a position that if there is any breakage, they can readily be cut adrift and thrown overboard.

ON CUTTING AND FITTING RIGGING.

On Cutting Lower Rigging.—Draw a line from the side of the partners abreast of the mast, on the deck, parallel to the channels, and to extend as far aft as they do. On this line mark the places of each dead-eye, corresponding to their places against the channels. Send a line up to the mast-head, and fasten it to the mast by a nail above the bibbs, in a range with the centre of the mast, and opposite to the side the channel line is drawn upon. Then take the bight of the line around the forward

part of the mast, and fasten it to the mast by a nail, opposite the first nail, so that the part between the nails will be half the circumference of the mast-head; then take the line down to the mark on the channel line for the forward dead-eye, and mark it as before; and so on, until you have got the distance between the mast and each mark on the channel line. Now cast off the line from the mast-head, and the distance between the end of the line and each mark will give you the length of each shroud from the lower part of the mast-head. And to make an allowance for one pair of shrouds overlaying another, you may increase the length of the pair put on second—that is, the larboard forward ones—by twice the diameter of the rigging, the third pair by four times, and so on.

The size of the lower rigging should be as much as eight and a half inches for vessels of 700 or 800 tons, and from seven and a half to eight inches for smaller vessels over 300 tons.

For the length of the fore, main, and mizen-stays, take the distance from the after part of the mast-head to their hearts, or to the place where they are set up, adding once the length of the mast-head for the collar.

The standing stays should be once and a half the circumference of the shrouds.

Fitting Lower Rigging.—Get it on a stretch, and divide each pair of shrouds into thirds, and mark the centre of the middle third. Tar, worm, parcel, and serve the middle third. Parcel *with* the lay of the rope, working towards the centre; and serve *against* the lay, beginning where you left off parcelling: serve as taut as possible. In some vessels the outer thirds of the swifter are served; but matting and battens are neater, and more generally used.

Formerly the middle third was parcelled over the service, below the wake of the futtock staff. Mark an eye at the centre of the middle third, by seizing the parts together with a round seizing. The eye of the pair of shrouds that goes on first should be once and a quarter the circumference of the mast-head; and make each of the others in succession the breadth of a seizing larger than the one below it.

Parcel the score of the dead-eye, and heave the shroud taut round it, turning in *with* the sun if right-hand-laid rope, and *against* the sun if hawser-laid; then pass the throat seizing with nine or ten turns, the outer turns being slacker than the middle ones. Pass the quarter seizings half way to the end, and then the end seizings, and cap the shroud, well tarred under the cap.

Make a Matthew Walker knot in one end of the lanyard, reeve the other end *out* through the dead-eye of the shroud, beginning at the side of the dead-eye upon which the end of the shroud comes, and *in* through the dead-eye in the channels, so that the hauling part of the lanyard

may come in-board, and on the same side with the standing part of the shroud. If the shroud is right-hand-laid rope, the standing part of the shroud will be aft on the starboard, and forward on the larboard side; and the reverse if hawser-laid.

The neatest way of setting up the lower fore-and-aft stays is by reeving them *down* through the bull's eye, with tarred parcelling upon the thimble, and setting them up on their ends, with three or four seizings. The collar of the stay is the length of the mast-head, and is leathered over the service. The service should go beyond the wake of the foot of the topsail, and the main-stay should be served in the wake of the foremast. The main and spring-stay usually pass on different sides of the foremast, and set up at the hawse-pieces.

Cutting and Fitting Topmast Rigging.—For the forward shroud, measure from the hounds of the topmast down to the after part of the lower trestle-trees, and add to that length half the circumference of the mast-head at the hounds. The eye is once and a quarter the circumference of the mast-head. The topmast rigging in size should be three-fifths of the lower rigging. For the topmast backstays, measure the distance from the hounds of the mast down to the centre of the deck, abreast of their dead-eyes in the channels, add to this length one-half the circumference of the mast-head. Add to the length of the larboard pair, which goes on last, twice the diameter of the rope. The size of the fore and maintopmast backstays is generally one quarter less than that of the lower rigging, and that of the mizentopmast backstays the same as that of the maintopmast rigging. The size of the topmast-stays should be once and a quarter that of the rigging. The topmast rigging is fitted in the same manner as the lower. The backstays should be leathered in the wake of the tops and lower yards. The breast backstays are turned in upon blocks instead of dead-eyes, and set up with a luff-purchase. The foretopmast-stay sets up on the starboard, and the spring-stay on the larboard side of the bowsprit.

All the fore-and-aft stays are now set up on their ends, and should be leathered in their nips, as well as in their eyes.

The maintopmast-stay goes through a heart or thimble at the fore-mast-head, or through a hole in the cap, and sets up on deck or in the top; and the mizentopmast-stay sets up at the mainmast-head, above the rigging.

Jib, Topgallant, and Royal Rigging.—The jib-stay sets up on its end on the larboard side of the head, and is served ten feet from the boom, and its collar is leathered like that of the topmast-stay. The gaub lines, or back ropes, go from the martingale in-board. The guys are fitted in pairs, rove through strap or snatches on the spritsail-yard,

and set up to the eye-bolts inside of or abaft the cat-heads. The foot ropes are three-quarters the length of the whole boom, and go over the boom with a cut splice. Overhand knot or Turk's-heads should be taken in them at equal distances, to prevent the men from slipping when laying out upon them.

The most usual method of fitting topgallant rigging in merchantmen is to reeve it through holes in the horns of the cross-trees, then pass it between the topmast shrouds over the futtock staff, and set it up at an iron band round the topmast, just below the sheave-hole; or else down into the top, and set it up there. Then get the length of the starboard forward shroud, measure from the topgallant-mast-head to the heel of the topmast, and add one-half the circumference of the topgallant-mast-head. Its size should be about five-sevenths of the topmast rigging. Each pair of shrouds should be served below the futtock staves. They are fitted like the topmast shrouds. The fore-and-aft stays of long topgallant-masts go with eyes, and are served and leathered in the wake of the foot of the sails. The fore-topgallant-stay leads in on the starboard side of the bowsprit, and sets up to a bolt at the hawse-piece; the main leads through a chock on the after part of the fore-topmast cross-trees, and sets up in the top and mizen usually through a thimble on the main cap, and sets upon its end.

The topgallant backstays set up on their end, or with lanyards in the channels; and for their length, measure from the mast-head to the centre of the deck, abreast the bolt in the channels.

The royal shrouds, backstays,* and fore-and-aft stays, are fitted like those of the topgallant-masts, and bear the same proportion to them that the topgallant bears to the topmast. The fore royal stay reeves through the outer sheave-hole of the flying jib-boom, and comes in on the larboard side; the main, through a thimble on the fore jack cross-tree; and the mizen, through a thimble at the maintopmast cap. The flying jib-stay goes in on the starboard side, and sets up like the jib-stay. The gear of the flying jib-boom is fitted like that of the jib-boom.

RATLING.—Swift the rigging well in, and lash handspikes or boat's-oars outside at convenient distances parallel with the shear-pole. Splice a smaller eye in the end of the ratlines, and seize it with yarns to the after-shroud on the starboard side, and to the forward on the larboard,

* "The plan adopted in some ships, of having the topgallant and royal backstays *singly*, with eyes like the stay, may be recommended in preference to the horse-shoe; for, though there are two eyes on the mast-head, yet when well fitted they do not look so clumsy as the horse-shoe, and are much safer, for it is a very common occurrence for backstays to be stranded in the nip of the grummet, or seizing. Those who imagine that they will look badly if single, have only to give the plan a trial to find themselves mistaken."—*The Mate and his Duties*, page 30.

so that the hitches may go *with* the sun. Take a clove hitch round each shroud, hauling well taut, and seize the eye of the other end to the shroud. The ratlines of the lower rigging should be thirteen, and of the topmast rigging eleven inches apart, and all square with the shear-pole.*

ON RIGGING SHIPS, ETC.

RIGGING SHEARS.—Shore the decks from the skin up, particularly abreast of the partners. Sling "skids" up and down the sides, for the purpose of keeping the shear-legs clear of the channels; reeve the parbuckles, and bring the shear-legs alongside, with their small ends aft; parbuckle them on board, and their heads or after-ends resting either on the taffrail, the brake of the poop, or a spar placed in the most convenient spot—the more elevated the better. Square the heels exactly one with the other, so that when they come to be raised, the legs may be found of equal height.

As near the after ends as may be considered necessary, when crossed, put on the head-lashing of new well stretched rope *(figure of* 8 *fashion)*, similar to a racking seizing, and cross with the ends. Open out the heels, carrying one over to each gangway, and placing it on a solid piece of oak or shoe, previously prepared for the purpose. Clap stout tackles on the heels, two on each—one leading forward, the other aft; set taut the after ones, and belay them. Lash a three or four fold-block, as the upper one of the main-purchase, over the main lashing (so that it will hang plumb under the cross), with canvas underneath to prevent chafing, and in such a manner that one-half the turns of the lashing may go over each horn of the shears, and divide the strain equally: also sufficiently long to secure the free action of the block. Lash the small purchase block on the after horn of the shears, sufficiently high for the falls to play clear of each other, and a girtline block above all.

Middle a couple of hawsers, and clove hitch them over the shear-heads; having two ends leading forward and two abaft, led through vial blocks, and stout luffs clapt on them. These should be sufficiently strong to secure the shears while lifting the masts.

* "The most approved method of ratling is, after the rigging is properly sparred and swiftered, to begin at the shear-pole, and work UPWARDS" . . . . making "the hitches right-handed which are formed on the shroud, before the other end is cut; and before cutting, the man should call out that he is ready to do so, that the mate may (by going to the opposite side of the deck or rail) be satisfied that it is properly put on. After rigging has been newly rattled, the spars should not be taken away till the tar about the hitches is well set."—*The Mate and his Duties*, page 32.

The lower-purchase block is lashed forward (perhaps round the cut-water), and the fall being rove, the shears are raised by heaving upon it, and preventing the heels from slipping forward, by means of the heel tackles previously mentioned.

Sometimes a small pair of shears are erected for the purpose of raising the heads of the large ones; in which case care must be taken to place them so as to allow the heads or horns of the other pair to pass through.

When the shears are up, or nearly perpendicular, *cleet the shoes*, so as to confine the heels to their places upon them. They then can be transported along the deck by means of the heel tackles and guys to the situation required, taking care to make them rest upon a beam, and to have the deck properly shored up below.

Finally, give the shears the necessary rake by means of the guys,* and set taut the guys and heel tackles. Also five or six feet above the deck, on each leg put two cleets, for the purpose of applying two stout lashings from *them above* to the dead-eyes in the channels *below*, in order to give greater security; this being done, the shears may be considered ready.

To TAKE IN THE MIZENMAST.—Tow the mizenmast alongside with the head aft, and the garland lashed on the forward part of the mast, above the centre; lash a pair of girtline blocks on the mast-head, and reeve the girtlines; bend the shear-head girtline to the mast below the bibbs, to *cant* it. Overhaul the main-purchase down abaft, thrust the strap through the eyes of the garland, toggle it, and secure the toggle by a back lashing. Take the fall to the capstan and "heave round;" when the heel rises near the rail, hook on a heel-tackle to ease it inboard. Get the mast fair for lowering by means of the girtlines, wipe the tennon dry, and tar both it and the step; "lower away," and step the mast.

Some distance may be saved by using no garlands, and having the purchase blocks lashed to the mast.† The mast being stepped and wedged temporarily, "come up" the purchases, man the guy and heel tackles, and transport the shears forward for taking in the mainmast.

The object of taking in the mizenmast first is, because the breadth of beam is less aft than forward, and the heels of the shears being spread more as they go forward, the head lashing consequently becomes

* The main-tackle must be brought nearly to the plumb of the mast-hole.

† The rule in this case is to take the height of the rail to the position of the lower block, when the tackle is block and block, and lash the lower block to the mast alongside, *at a less distance from the heel than from the block to the rail*, and must be above the part that takes the combings.

tauter; moreover, if the mizenmast was taken in *last* the bowsprit must be got in *first*, and thus the advantage of securing the shears to the foremast-head when getting in the bowsprit would be lost.

To take in the Main and Foremast.—Proceed in the same manner as in getting in the mizenmast, rousing the shears forward with their shoes, by means of the heel tackles. It is better not to use garlands, when the shear legs are rather short, as lashing the purchase blocks to the mast shortens the distance. If the ship has a topgallant-forecastle, it would be well to step the mast forward of the shear legs, for the brake of the forecastle comes abreast of the partners; and in a case of this kind it would be well to take in the foremast first.

To take in the Bowsprit.—Having stepped and secured the foremast, carry the forward guys aft and rake the shears over the bow; toggle the lower block of the main-tackle to a garland lashed to the upper part of the bowsprit, inside of the centre. Put on the cap, and carry tackles or guys from the bowsprit-head to the cat-head, and clap on a heel-tackle or guy. Heave the bowsprit, and direct it by the small tackles and guys.

If the ship has a topgallant-forecastle, the bowsprit cannot be taken in with the shears without the assistance of a *derrick*, on account of the brake of the forecastle, it not being prudent to step shears on the top of it.

Sending a Trestle-tree aloft.—One girtline is used, the trestle-tree is slung with a span, so as to hang square, and to keep the girtline clear of the midship part which is to land on the hounds of the mast.

When both trestle-trees are in their places, they are bolted together through the mast-head. (A rope is clove-hitched round the mast-head for the men to steady themselves with whilst working aloft.)

To place a Lower Cross-Tree.—One girtline is bent to the cross-tree on its own side, and is stopped to the opposite arm amidships. —"Sway away." When above the trestle-tree cut the upper stop, it will then hang square. The men aloft place and bolt it down to the trestle-trees.

To get the Tops over the Mast-heads.—Place the top on deck abaft the mast; get a girtline on each side of the mast-head, and pass the end of each under the top, through the holes in the after part; clinch them to their own parts, and stop them to the fore part of the top with slip-stops. Have a guy to the fore, and another to the after part of the top. Make the ends of a span fast to the after corners of the top, and bend a girtline from the mast-head to the bight of the span, and stop it to the forward part of the top. Sway away on the girtlines. When the fore part of the top is above the trestle-trees, cut the span-

stops; and when the after part is above them, cast off the slip-stops. When the lubber-hole is high enough to clear the mast-head, haul on the forward guy, and let the top hang horizontally by the girtlines. Lower away, place, and bolt it.

The tops may be got over without the span and girtline, by stopping the two girtlines first rove to the middle as well as to the fore part of the top, and cutting the upper stops first. The fore and main tops are sent up from abaft, and the mizen from forward.

Rigging the Fore, Main, and Mizenmasts.—Before the trestle-trees are sent up, white-lead the mast-head in the wake of them; overhaul down the girtlines, and bend on the trestle-trees, with the after chock out, "sway away;" when above the bibbs, slip the stops so as to let them come down gradually into their places; then the after chock is sent up, let in and bolted. Tar the mast-head in the way of the rigging; overhaul again the girtlines for the bolsters, which are covered well with tarred canvas; sway them aloft and stop them. The girtline blocks are now lashed to the after part of the trestle-trees. Next the shrouds are hoisted over the mast-head—the starboard forward shroud first; then the larboard; and so on, alternately, taking care that the seizing aloft bears in a parallel direction, between the two lower dead-eyes which the shrouds will be set up to. As each pair of shrouds are put over the mast-head, drive them down as close as possible; the stay is now to be placed abaft, and below all.

To Rig a Bowsprit.—Lash collars for the forestay, bobstays, and bowsprit shrouds, then for the spring stay, and put on the bees for the topmast stays; fit the manropes, pass the gammoning, and set up bobstays and shrouds.

To send up a Topmast.—Get the topmast alongside, with its head forward. Lash a top-block to the head of the lowermast; reeve a mast-rope through it, from aft forward, and bring the end down through the trestle-trees and reeve it through the sheave-hole of the topmast, hitching it to its own part a little below the topmast-head, and stopping both parts to the mast at intervals. Snatch the rope, and sway away. As soon as the head is through the lower cap, cast off the end of the mast-rope, letting the mast hang by the stops, and hitch it to the staple in the other end of the cap. Cast off the stops, and sway away. Point the head of the mast between the trestle-trees and through the hole in the lower cap, the round hole of which must be put over the square hole of the trestle-trees. Lash the cap to the mast, hoist away, and when high enough, lower a little and secure the cap to the lowermast-head. (This is when it cannot be put on by hand.)

To send Topmast Cross-trees up.—If the cross-trees are heavy, they

may be placed in the following manner: —Sway away until the topmast-head is a few feet above the lower cap. Send up the cross-trees by girtlines, and let the after part rest on the lower cap, and the forward part against the topmast. Lower away the topmast until the cross-trees fall into their place, and then hoist until they rest on the shoulders.

PLACING TOPMAST RIGGING.—Tar the mast in the wake of the rigging, and clothe the bolsters as the lower ones; then place the span for gin blocks. Some prefer chain spans to shackle the iron-bound block to. The most approved method is an iron plate with a hook on each end, which lays across the trestle-trees. Next put over the mast-head pendants; then follow the strops with thimble in for standing part of the tyes. The shrouds are swayed up and placed over the topmast-head; the first pair on the starboard forward, then the larboard, and so on with the other pairs. Backstays are hoisted and placed the same as shrouds; stays are swayed up and lashed abaft the topmast-head.

TO CROSS A LOWER YARD.—Bring it alongside with the opposite yard-arm forward, reeve the yard-rope through the jeer block of the mast-head, make it fast to the slings of the yard, and stop it out to the yard-arm. Sway away, and cast off the stops as the yard comes over the side, and get the yard across the bulwarks. Lower yards are rigged now with iron trusses and quarter-blocks, which would be fitted before rigging the yard. Seize on the clew-garnet-block, and put the rigging over the yard-arm; first the stops for the head-earrings, then the foot-ropes, then the brace blocks or pennants, and last the eye of the lift. (The lifts, brace pennants, and foot-ropes are now spliced or hooked into rings with thimbles on an iron band, round the yard-arm next the shoulders. In this way, there is no rope of any kind round the yard-arm.) Reeve the lifts and braces, get two large tackles from the mast-head to the quarters of the yard, and sway away on them and on the lifts, bearing off and sluing the yard by means of guys. Secure the yard by the iron trusses, and haul taut lifts and braces.

TO CROSS A TOPSAIL-YARD.—As topsail-yards now have chain-tyes, there are no tye-blocks to seize on. The quarter-blocks are first seized on, and the parral secured at one end, ready to be passed. A single parral has an eye on each end, and one end is passed under the yard and over, and the eye seized to the standing part, close to the yard. After the yard is crossed, the other end is passed round the mast, then round the yard, and seized in the same manner. To pass a double parral, proceed in the same manner, except that the seizings are passed so as to leave the eyes clear and above the standing part, and then take a short rope with an eye in each end, pass it round the mast, and seize the eyes to the eyes of the first long rope. The parral is wormed,

served, and leathered. The parral being served at one end, put on the head-earring strops, the foot ropes, Flemish horses, and brace blocks. Bend the yard-rope to the slings, stop it out to the yard-arm, and sway away until the yard is up and down; then put on the upper lift in the top and the lower lift on deck, and reeve the braces. Sway away, cast off the stops, and take in upon the lower lift as the yard rises, till the yard is square; then haul taut lifts and braces, and pass the parral.

The Mizen Topsail-Yard is rigged nearly the same as the main and mizen; but the brace blocks are on the foreside, and the Flemish horses generally spliced into bolts in the ends of the yards, with round thimbles in them.

To Cross a Topgallant-yard.—Seize on the parral and quarter-blocks; reeve the yard-rope through the sheave-hole of the topgallant-mast, make it fast to the slings of the yard, and stop it out to the upper end. Sway away, and when the upper yard-arm has reached the top-mast-head, put on the upper lift and brace; sway away again, put on the lower lift and brace, cast off all the stops, settle the yard down square by lifts and braces, and pass the parral lashing.

Joining Ship and Fitting Her Out.—Suppose you join a ship having only her lowermasts and bowsprit standing—first, secure the bowsprit by means of the bobstays, gammoning, and shrouds; next get the tops over the mast-head; then tar and parcel the bolsters well, and place them; then get the rigging over the mast-head in the order stated before; set the rigging up, and stay it; next, get the lower cap on, the topmast up, topmast cross-tree on, topmast rigging over, &c.

ON MAKING AND TAKING IN SAIL.

To Set a Course.—Loose the sail, and overhaul the buntlines and leech-lines. Let go the clew-garnets and overhaul them, and haul down on the sheets and tacks. If the ship is close-hauled, ease off the lee-brace, slack the weather lift and clew-garnet, and get the tack well down to the water ways. If it is blowing fresh, and the ship light handed, take it to the windlass. When the tack is well down, sharpen the yards up again by the brace, top it up well by the lift, haul aft the sheet, reeve and haul out the bowline.

If the wind is quartering, the mainsail is carried with the weather-clue hauled up and the sheet taken aft.

To Set a Topsail.—Loose the sail, and keep one hand in the top to overhaul the rigging. Overhaul well the buntlines, clewlines, and

reef-tackles; let go the topgallant-sheets and topsail-braces, and haul home on the sheets. Merchant vessels usually hoist a little on the halyards, so as to clear the sail from the top; then belay them, and get the lee-sheet chock home; then haul home the weather-sheet, shivering the sail by the braces to help it home, and hoist on the halyards until the leeches are well taut, taking a turn with the braces if the wind is fresh, and slacking them as the yard goes up.

After the sail is set, it is sometimes necessary to get the sheets closer home. Slack the halyards, lee-brace, and weather-bowline; clap the watch-tackle upon the lee-sheet first, and then the weather one, shivering the sail by the braces, if necessary. Overhaul the clewlines and reef-tackles, slack the topgallant sheets, and hoist the sail up, taut leech, by the halyards.

To Set a Topgallant-sail or Royal.—Haul home the lee-sheet, having one hand aloft to overhaul the clewlines, then the weather-sheet, and hoist up, taut leech, by the halyards. While hauling the sheets home, if on the wind, brace up a little to shake the sail, take a turn with the weather-brace, and let go the lee one; if before the wind, let go both braces; and if the wind is quartering, the lee one.

To Loose a Sail.—Lay out to the yard-arms and cast off the gaskets, beginning at the outermost and coming in.* When the gaskets are cast off from both yard-arms, then let go the bunt gasket (and jigger, if there be one), and overhaul the buntlines and leechlines.

Taking in a Course in a Gale of Wind.—Steady the yard as securely as possible, man the clew-garnets, buntlines, and leechlines; ease off the sheet a little, let go the bowline, and ease away the tack; haul up to windward, ease off the sheet, haul up, get the sail close to the yard and furl it.

To Take in a Topsail in a Gale of Wind.—The yard being braced up, lower away handsomely on the halyard; get the yard down by the clewlines and reef-tackles, rounding it on the weather-brace, and steadying the yard by both braces. Then let go the weather-sheet, and haul up to windward first. The weather-clew being up, let go the lee-sheet and haul up by the clewline and buntlines, keeping the clew in advance of the body of the sail.

Sometimes, if the weather-brace cannot be well rounded in, as if a ship is weak-handed, the sail may be clewed up to leeward a little first —in which case, ease off the lee-sheet, and haul up on the clewline; ease off the lee-brace and round the yard in, and when the lee-clew is about half up, ease off the weather-sheet and haul the weather-clew

* If only one yard-arm is loosed at a time, let the lee one be loosed first.

chock up. Haul the buntlines up after the weather-clew, and steady the yard by the braces. There is danger in clewing up to leeward first, that the sail might be shaken and jerked so as to split, before the weather-clew is up; whereas, if clewed up to windward first, the lee-clew will keep full, until the lee-sheet is started.

When coming to anchor, it is the best plan to haul the clews about half up before the halyards are let go.

In taking in a close-reefed topsail in a gale of wind, the most general practice is to clew up to windward, keeping the sail full; then lower away the halyards and ease off the lee-sheet, clew the yard down, and haul up briskly on the lee-clewline and the buntlines, bracing to the wind the moment the lee-sheet is started.

To Take in a Topgallant-sail or Royal—Blowing Fresh.—If the wind is very fresh, and the vessel close-hauled, a good practice is to let go the lee-sheet and halyards, and clew down, rounding in at the same time on the weather brace. Then start the weather-sheet, and haul the weather-clew chock up. Haul up the buntlines, and steady the yard by the braces.

To Take in a Topmast-studdingsail.—Ease off the sheet, lower away handsomely on the halyards, clewing the yard down to the outer-clew by the downhaul. Slack up the tack and lower away on the halyards, hauling down well on the sheet and downhaul, till the sail is in upon the forecastle.

To Take in a Lower-studdingsail.—Let go the outhaul and trip the sail till the outer clew is up to the yard. Then lower away the outer-halyards, and haul in on the sheet and tripping-line.

When the sail is in over the rail, lower away the inner-halyards.

To Unbend a Course.—First furl the sail, then cast off the robands, and make the buntlines fast round the sail. Ease the earrings off together, and lower away by the buntlines and clew-garnets. At sea the lee-earring is cast off first, rousing in the lee body of the sail, and securing it by the earring to the buntlines.

To Unbend a Topsail.—Clew it up, cast off the robands, secure the buntlines round the sail, unhook the sheets, and unreeve the clewlines and reef-tackles, ease off the earrings, and lower by the buntlines.

A Topgallant-sail is unbent in the same manner, and sent down by the buntlines. A Royal is usually sent down with the yard.

When it is blowing fresh, and the topsail or course is reefed, to send it down you must cast off a few robands and reef points, and pass good stops around the sail; then secure the buntlines also round it, and cast off all the robands, reef-points, and reef-earrings.

Bend a line to the lee-head-earring, and let it go; haul the sail well

up to windward and make fast the lee-earring to the buntlines. Get a hauling line to the deck, forward; ease off the weather-earring, and lower away.

To Reef a Topsail.—Round in on the weather-brace, ease away the halyards, and clew the yard down. Point the yard to the wind, haul out the reef-tackles, and haul taut the buntlines. As soon as the men are off the yard, let go the gear; man the halyards, let go the lee-brace, slack off the weather one, and hoist away. When well up, trim the yard by the braces and haul out the bowlines.

Bending a Course in Blowing Weather.—Stretch the head of the sail across the deck as near as possible; bend the gear, then bring the leeches of the sail as near where they will haul up on the yard as possible; then stop the sails well about every two or three feet; besides the yard buntlines, have one in midships of the sail. When ready, man all together, and run it up to the yard; by this means the sail may be bent and furled with very little difficulty.

Bending a Topsail in a Gale.—Reef it by the foot, which is done in the following manner:—Stretch the close-reef of any sail taut along the deck; take the clews as near where they will haul up on the yard as possible; brace the clews down clear to the foot of the sail, then haul taut the foot of the sail without moving the clews out of their places; then gather the foot as near the close-reef as possible, then tie the reef round the foot, then the third reef, until all the reefs are expended round the foot of the sail; minding to keep the reef-knots as near at hand as possible to be ready for casting off. By this means the sail may be bent without exposing more than one reef at a time until the close-reefed sail is set.

Note.—A topsail might be sent up by the buntline and weather-clewline.

TACKING, WEARING, BOXING, ETC.

Tacking.—If the mainsail be hauled before the wind comes ahead, the mainyard will fly round of itself; but if it be not hauled until the wind comes ahead, or on the other bow, it will occasion a very dead haul.

If she falls off too rapidly while swinging your head-yards, so as to bring the wind abeam or abaft, *'Vast bracing!* Ease off head-sheets, and put your helm a-lee; and as she comes up, meet her and brace sharp up. If, on the other hand (as sometimes happens with vessels which carry a strong weather helm), she does not fall off after the after

sails take, be careful not to haul your head-yards until she is fully round; and if she should fly up in the wind, let go the main-sheet, and, if necessary, brail up the spanker and shiver the cross-jack yards.

In staying, be careful to right your helm before she loses head-way.

To Tack without Fore-reaching.—As in a narrow channel, when you are afraid to keep your head-way. If she comes slowly up to windward, haul down the jib and get your spanker-boom well over to windward. As you raise tacks and sheets, let go the lee-foretopsail-brace, being careful to brace up again as soon as she takes aback. Also, hoist the jib, and trim down, if necessary, as soon as she takes on the other side.

Tacking against a Heavy Head-sea.—You are under short sail, there is a heavy head-sea, and you doubt whether she will stay against it. Haul down the foretopmast-staysail, ease down the helm, and raise fore-sheet. When within a point of the wind's eye, let go main-tack and sheet, lee-braces and after bowlines, and *Mainsail haul!* If she loses her head-way at this time, shift your helm. As soon as she brings the wind on the other bow, she will fall off rapidly by reason of her stern-way, therefore shift your helm again to meet her, and *Let go and haul!* at once. Brace about the head-yards, but keep the weather braces in, to moderate her falling off. When she gets head-way, right the helm; and as she comes up to the wind, brace up and haul aft.

To Trim the Yards when Close-hauled.—In smooth water, with a light breeze, brace the lower yards sharp up, and trim the upper yards each a trifle in abaft the one below it. If you have a pretty stiff breeze, brace the topsail-yard in about half a point more than the lower yard, and the topgallant-yard half a point more than the topsail-yard, and so on. If you have a strong breeze and a topping sea, and especially if reduced to short sail, brace in your lower yards a little, and the others proportionally.

This will prevent the vessel going off bodily to leeward; and if she labours heavily, the play of the mast would otherwise carry away the braces and sheets, or spring the yards.

Missing Stays.—If, after getting head to the wind, she comes to a stand and begins to fall off before you have hauled your main-yard, flatten in your jib-sheets, board fore-tack, and haul aft fore-sheet; also ease off spanker-sheet, or brail up the spanker, if necessary. When she is full again, trim the jib and spanker-sheets; and when she has recovered sufficient head-way, try it again. If, after coming head to the wind, and after the after yards are swung, she loses head-way and refuses to go round, or begins to fall off on the same tack on which she was before, and you have shifted the helm without effect, haul up the

mainsail and spanker, square the after yards, shift your helm again a-lee, so as to assist her in falling off, and brace round the head yards so as to box her off. As she fills on her former tack, brace up the after yards, brace round the head yards, sharp up all, board tacks, haul out and haul aft.

To Wear a Ship.—Haul up the mainsail and spanker, put the helm up, and as she goes off, brace in the after yards. If there is a light breeze, the rule is to keep the mizentopsail lifting, and the maintopsail full. This will keep sufficient head-way on her, and at the same time enable her to fall off. But if you have a good breeze, and she goes off fast, keep both the main and mizentopsails lifting. As she goes round, bringing the wind on her quarter and aft, follow the wind with your after yards, keeping the mizentopsail lifting, and the main either lifting or full, as is best. After a vessel has fallen off much, the less head-way she has the better, provided she has enough to give her steerage. When you have the wind aft, raise fore-tack and sheet, square in the head-yards, and haul down the jib. As the wind comes upon the other quarter, brace sharp up the after yards, haul aft the mizen and mizenstaysail-sheets, and set the mainsail. As she comes to on the other tack, brace up the head-yards, keeping the sails full, board fore-tack and aft the sheet, hoist the jib, and meet her with the helm.

To Wear under Courses.—Square the cross-jack yards, and haul up the mainsail. Square the main-yards and put the helm a-weather. As she falls off, let go the fore-bowline, ease off the fore-sheet, and brace in the fore-yard. When she gets before the wind, board the fore and main-tacks on the other side, and haul aft the main-sheet, but keep the weather-braces in. As she comes to on the other side, ease the helm amidships, trim tack and fore-sheet, brace up and haul out bowlines.

To Wear under a Mainsail.—Vessels lying-to under this sail generally wear by hoisting the foretopmast-staysail, or some other head sail. If this cannot be done, brace the cross-jack yards to the wind, and, if necessary, send down the mizentopmast and the cross-jack yard. Brace the head-yards full. Take an opportunity when she has head-way, and will fall off, to put the helm up. Ease off the main-sheet, and as she falls off, brace in the main-yard a little. When the wind is abaft the beam, raise the main-tack. When she is dead before it, get the other main-tack down as far as possible; and when she has the wind on the other quarter, ease the helm, haul aft the sheet, and brace up.

To Wear under Bare Poles.—To assist the vessel, veer a good scope of hawser out of the lee-quarter, with a buoy, or something for a stop-water attached to the end. As the ship sags off to leeward, the buoy

will be to windward, and will tend to bring the stern round to the wind. When she is before it, haul the hawser aboard.

If the vessel will not go off, it will be necessary, as a last resort, to cut away the mizenmast, veer away the hawser, and use the mizentopmast as a drag to assist in wearing.

To Wear a Ship under Close-reefed Maintopsail and Storm-staysail.—Have lifts, trusses, and rolling tackles attended, so that the yard and topmast may be well supported in the heavy rolling they are likely to experience. Haul down the mizen-storm-staysail, and when she falls off, up helm; ease off the main-storm-staysail sheet, and brace in the main and cross-jack yards, at the same time taking care to keep the maintopsail full, to preserve the head-way, and to keep her ahead of the sea; also to keep it from splitting. When the wind is on the quarter, haul down the main-storm-staysail, and shift over the sheet; when before the wind, right the helm, and square the head-yards; shift over the fore-storm-staysail sheet; watch for a smooth time to bring-her-to; then ease down the helm, hoist the mizen-storm-staysail, and when the wind is on the quarter, brace up the head-yards, hoist the main-storm-staysail, haul aft the fore-storm-staysail sheet, meet her with the helm, trim the sails, and haul the maintop-bowline.

Box-hauling a Ship.—Put the helm down, light up the head-sheets and slack the lee-braces, to deaden her way. As she comes to the wind, raise tacks and sheets, and haul up the mainsail and spanker. As soon as she comes head to the wind and loses her head-way, square the after yards, brace the head-yards sharp aback, and flatten in the head-sheets. The helm being put down to bring her up, will now pay her off as she has stern-way on. As she goes off, keep the after sails lifting, and square in the head-yards. As soon as the sails on the foremast give her head-way, shift the helm. When she gets the wind on the other quarter, haul down the jib, haul out the spanker, set the mainsail, and brace the after yards sharp up. As she comes to on the other tack, brace up the head yards, meet her with the helm, and set the jib.

Club-hauling a Ship.—This method of going about is resorted to when on a lee-shore, and it is expected a ship will miss stays. Cock-bill your lee-anchor, get a hawser on it for a spring, and lead it to the lee-quarter; range your cable, and unshackle it abaft the windlass. *Helm's-a-lee!* and *Raise tacks and sheets!* as for going in stays. The moment she loses head-way, let go the anchor, and *Mainsail haul!* As soon as the anchor brings her head to the wind, let the chain cable go, holding on to the spring; and when the after sails take full, cast off or cut the spring, and *Let go and haul!*

On a Lee-shore, not room to Veer or Stay—No Anchorage—Put

the helm a-lee, and when she comes head to wind, let go tacks and sheets, and haul them all aback; get in the lee-tacks, so that the vessel may pay short round on her heel, and when the mainsail shivers, haul it up; when she gathers head-way, shift the helm, and when the wind is on the quarter, shift the spanker, mainsail, &c., and bring her close to the wind.

GALES OF WIND, LYING-TO, ETC.

LYING-TO.—It is generally thought that the best single sail to lie-to under is a close-reefed maintopsail. The fore or the main-spencer, which sails are now very much used instead of main and mizen-staysails, may be used to advantage, according as a ship requires sail more before or abaft the centre of gravity. If a ship will bear more than one sail, it is deemed best to separate the pressure. Then set the fore and main-spencers; or, should she carry staysails instead, the main and mizen-staysails; or, if she is easier under lofty sail, the fore and maintopsails close-reefed. A close-reefed maintopsail, with three lower storm-staysails; or with the two spencers, foretopmast-staysail, and reefed spanker, is considered a good arrangement for lying-to. If the foretopmast-staysail, and balance-reefed spanker can be added to the two close-reefed topsails, she will keep some way, will go less to leeward, and can be easily wore round. Close-reefed topsails are used much more now for lying-to than the courses. As ships are now built with the centre of gravity further forward, and the foremast stepped more aft, they will lie-to under head sail better than formerly. Some vessels, which are well down by the stern, will lie-to under a reefed foresail, as this tends to press her down forward; whereas, if she had much after sail, she would have all the lateral resistance of the water aft, and would come up to the wind. In carrying most head or after sail, you must be determined by the trim of the vessel, her tendency to come to or go off, and as to whether the sail you use will act as a lifting or a burying sail.

A topsail has an advantage over a spencer or lower-staysail for lying-to, since it steadies the ship better, and counteracts the heavy roll which a vessel will give under low and small fore-and-aft sails.

SCUDDING.—When scudding in a heavy gale of wind, care should be taken that sufficient of lofty sail should be carried on the vessel to keep her freely and fairly *before* the sea. A ship will scud better with the sea right aft than quartering. With a heavy sea, the danger to be apprehended is, that the wave, travelling faster than the ship, may overtake

and break over her. For scudding, the most approved sail seems to be the close-reefed maintopsail, with a reefed foresail. The course alone might get becalmed under the lee of a high sea, and the vessel losing her way, would be overtaken by the sea from aft; whereas the topsail will always give her way enough and lift her. The foresail is of use in case she should be brought by the lee. It has been recommended that the foretopmast-staysail or fore-storm-staysail should always be set in scudding, to pay her off if she should broach-to, and with the sheets hauled flat aft.

With the wind quartering and a heavy sea, it is deemed that a vessel is more under command with a close-reefed foretopsail and maintopmast-staysail. The foretopmast-staysail may also be hoisted. If the ship flies off and gets by the lee, the foretopsail is soon braced about, and, with the maintopmast-staysail-sheet shifted to the other side, the head-way is not lost.

Scudding—Broaches-to.—This is when a vessel is scudding, and comes up into the wind and gets aback. For such an accident the fore-topmast-staysail is set, which will act as an off-sail, so that by keeping the helm up, with the maintopsail (if set) braced into the wind, she will pay off again without getting stern-way. If the close-reefed foretopsail is carried instead of the main, it can be easily filled.

Scudding—Brought by the Lee.—This is when a vessel is scudding with the wind quartering, and falls off so as to bring the wind on the other side, laying the sails aback. This is more likely to occur than broaching-to, especially in a heavy sea. Suppose the vessel to be scud-ding under a close-reefed maintopsail and reefed-foresail, with the wind on her larboard quarter. She falls off suddenly and brings the wind on the starboard quarter, laying all aback. Hard a-starboard your helm, raise fore-tack and sheet, and fill the foresail, shivering the maintopsail. When she brings the wind aft again, meet her with the helm, and trim the yards for her course.

On Rounding-to in a Gale.—An experienced seaman remarks, that when he wished to bring-to in a hard gale, when running before a heavy sea, he always watched for a heavy sea breaking abaft the main chains, and immediately after he eased the helm down, and rounded-to at once, having previously prepared for doing so. In managing this way he found he could avoid shipping a sea.

Taken Aback.—It will frequently happen, when sailing close-hauled, especially in light winds, from a shift wind, from it dying away, or from inattention, that the ship will come up into the wind, shaking the square sails forward. In this case it will often be sufficient to put the helm hard up, flatten in the head-sheets, or haul their bights to windward,

and haul up the spanker. If this will not recover her, and she continues to come to, box her off. Raise fore-tack and sheet, haul up the spanker and mainsail, brace the head-yards aback, haul the jib-sheets to windward, and haul out the lee-bowlines. When the after sails fill, *Let go and haul!* This manœuvre of boxing can only be performed in good weather and light winds, as it usually gives a vessel stern-way.

If the wind has got round upon the other bow, and it is too late for box-hauling, square the yards fore-and-aft, keeping your helm so as to pay her off under stern-way: and, as the sails fill, keep the after yards shaking, and haul up the spanker and mainsail, squaring the head-yards and shifting your helm as she gathers head-way.

Suppose that, instead of coming-to, you are taken aback in light winds. Put the helm up if she has head-way, haul up the mainsail and spanker, and square the after yards. Shift the helm as she gathers stern-way; and when the after sails fill and she gathers head-way, shift the helm again. When she brings the wind aft, brace up the after yards, get the main-tack down and sheet aft, and haul out the spanker as soon as it will take. The head braces are not touched, but the yards remain braced as before.*

ON THE MANAGEMENT OF SHIPS AT SINGLE ANCHOR.†

Anchor Turning in the Ground.—In order to insure the certainty of an anchor turning in the ground with the tending or swinging of the ship, it is recommended (whenever it is possible to resort to this practice) to shoot the ship on the same side of her anchor, at each change of tide; for if the anchor should not turn in the ground, the cable will get foul, either about the stock or upper fluke, and trip it out of the ground.

To Tend to a Weather Tide.—Let it be supposed that a ship is riding at single anchor, upon a lee tide, with the wind in the same direction as the tide, and that it be required, upon the tide setting to windward, to tend the ship clear of her anchor. To effect this, as soon as the ship begins to feel the turn of the weather tide, and that the vessel brings the wind broad on the weather-bow, the head sails should

* The former mode of wearing by squaring the head-yards, when the after-yards are full, has a great advantage over the latter method, as the vessel will go off faster when the wind is abeam and abaft, and will come-to quicker when the wind gets on the other side.

† See *The Anchor Watch*, an admirable little book on this subject, published by J. D. Potter, 31, Poultry, London.

be hoisted, and the lee sheets hauled aft, in order to shoot the ship from her anchor, on a taut cable. The helm must be put "a-lee," and kept in that position until the tide sets the ship over to windward of her cable, and the buoy appears on the same side with the helm. If from light winds the buoy bears nearly abeam, her head sails may be hauled down; but if the breeze be strong, and it causes the ship to shoot in a direction nearly end-on with that of the cable, bringing the buoy on her quarter, it will be necessary to keep the foretopmast-staysail set, in order to check the vessel, should she be disposed to break her shear against the action of her helm, or be inclined to drop to windward and "go over" her anchor, in a broadside or lateral direction.

To Keep the Hawse Clear when Moored.—When it is nearly slack water, cant her with the helm the right way, and, if necessary, make use of jib, spanker, and yards.

To Tend to Windward.—When the tide slacks, shear her with the helm, run up the jib and foretopmast-staysail, with weather-sheets aft; when canted the right way, the lee-sheets may be hauled aft, and the yards filled, thus setting her abreast to a taut cable; when the buoy is on the lee-quarter, brace the head-yards to the wind, and fill the after ones; when the tide swings her head round so as to shake the sails, haul down and stow them.

To Tend to Leeward.—As the tide slackens, shear her to the same side of the buoy on which she came to windward, and fill the yards, which will set her end-on over the cable; she will now, by the effect of the wind, bring her stern over the cable, and bring the buoy on the weather-quarter; put the helm "a-weather," and she will shoot ahead, tautening the cable by shearing her head from the wind. When the wind gets a little aft the beam, hoist the jib to prevent the cable from drawing her head to wind.

Let her lie in this position until she falls off; when the head sails shake, haul down and stow them.

To Break the Shear.—When tending to the tide, and the ship comes over her anchor, she may break her shear by canting her stern the wrong way; when this is the case put the helm "a-weather," run the jib up, fill the head-yards, and the after-yards kept to. Everything is now arranged to bring her round again, when she must be managed as before mentioned.

Note.—In Taylor's instructions for the management of ships at single anchor, which are universally read by mariners, it is recommended "always to shear a ship to windward, for if the wind is blowing across the tide, or nearly so, the cable is eased of a great part of the strain by keeping the helm a few spokes down; but it must not be supposed that a ship should be kept always to windward of the anchor, for it is impossible to do so except in a very deep ship, and during the strength of the

tide. On the contrary, a ship should, as long as it is practicable, be kept to leeward of her anchor. If when blowing hard, she has been kept to windward during the strength of the tide, she should be sheared to leeward as soon as it slackens. In bad holding ground the shear should be against the rise of the ground, without reference to the wind, as long as the tide runs with any strength. If on the weather tide—that is, with the wind against the tide, or on the ship's quarter—she forges ahead and brings the buoy on the weather quarter, she is safe enough as long as it can be kept there; but the danger of this position is, in case the wind freshens, her head may fly off from the wind, bringing it on the other quarter, and, in consequence, make a long and dangerous sweep to leeward: therefore, the foretopmast-staysail must not be set too soon—and if the yards have been pointed to the wind, the after yards should be braced round and kept full, so that if the wind does come upon the other quarter, they may be pointed.

"Sometimes a laden ship will not keep in this position without frequently breaking her shear, and it is in this case that tending to windward becomes necessary—a very troublesome manœuvre, and one where it is always requisite to have more canvas than the foretopmast-staysail. If, when the buoy is on the weather quarter, a sufficient strain has been on the cable to warrant the supposition that the anchor has been slued to leeward, she can be set to windward with the yards and staysails, without coming again astream of the anchor; but if the chain has not been very taut, it is always better to watch a lull, and set her to windward when astream of it. If this cannot be done, and she still keeps ahead of the chain, she may be set to windward; but while there, care must be taken that she does not drop astream of it, and when the lee tide makes, she should at first get a broad shear to leeward to insure the anchor being drawn properly round, and afterwards sheared to windward if necessary.

"If, while riding on the weather tide and sheared to windward, she forges ahead and brings the buoy on the lee quarter, sufficient canvas must be kept set to keep her ahead of the buoy, lest by dropping astream and falling to leeward the bight of the chain be thrown round the upper fluke of the anchor. In light winds and slack tides the anchor is not drawn round at all; therefore, care must be taken to swing the vessel always on the same side of it, so that if, while riding on the weather tide, she was sheared and tended to windward, it becomes necessary to tend her again to windward when the lee tide ceases—a thing that is very difficult to do; if the wind is much across, she must be shot across the tide to windward with the main and foretopmast-staysails, assisted by the jib and other fore-and-aft canvas if necessary, and kept there till the weather tide makes. Except in light winds, it is not always prudent to sight the anchor very often; for in some places it is a chance whether or not it will take hold again, so that all attention should be paid to the tending or swinging."—*The Mate and his Duties*, pp. 25—26.

MOORING,* UNMOORING, ETC.

Getting Under Way from a Single Anchor.—See all ready forward for getting under way; the rigging fair for making sail, the cat and

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* The old fashion of mooring ships with an anchor on either side—that is to say, supposing the prevailing wind north, the anchors should be laid east and west—has long been exploded. It has been shown that the combined strength of two cables so placed is equal only to one-sixth of a single chain laid in the direction of the wind. See *An Enquiry relative to various Important Points of Seamanship*, by Nicholas Tinmouth. The reader is strongly recommended to a perusal of Mr. Tinmouth's work, being a scientific inquiry into subjects with which it should be the object of every officer to make himself acquainted, but which few have the opportunity of practically investigating in the ordinary course of the merchant service.

fish tackles rove, and the fish davit at hand. Heave short on your chain, and pawl the windlass. Loose all the sails if the wind is light, and sheet home and hoist up topsails, topgallantsails, and royals. If there is a stiff breeze, set topsails alone, whole or reefed. You should always, if it will answer, cast on the opposite side from your anchor; that is, if you are riding by your starboard anchor, cast to port. Brace your head-yards aback and your after yards full, for the tack you mean to cast upon. The sails being set, man the windlass again, give her a shear with the helm, and trip your anchor. As soon as your anchor is aweigh, hoist the jib. The foretopsail aback will pay her head off. Put the helm for stern-board. When her head is off enough, fill away the head-yards and haul out the spanker, shifting the helm for head way. Trim the yards for your course, and make sail on her. If the wind is light and the sea smooth, you may cat and fish your anchor after you get under way; but it is best in a rough sea to keep the vessel hove-to until the anchor is catted and fished.

To make sure of Casting the Ship the right way.—From unforeseen changes of wind and weather, it becomes unsafe to remain at anchor, and doubts are entertained of the ship casting the right way, the ship should be cast by means of a spring, and the cable slipped—to effect which, the stream cable or a good hawser should be got out of the quarter, and bent to the riding cable outside the hawse-pipe on the opposite side, and hove taut, but kept clear for letting go and running. Veer away the riding cable, having previously unshackled it; and when the ship has been sufficiently canted for the sails to act, and she begins to draw ahead, slip, or cut if necessary, the slipped part of the bower chain having been previously buoyed.

Coming-to in a Tide-way.—If a ship be running over a weather-tide, with the wind on her port quarter, and it be required to ride to leeward, it is plain that the port anchor will be most serviceable, as the chain will not cross the cut-water or touch the copper in bringing up. If the wind be so strong that she will stem the tide after the sails are clewed up, she will not lay astream of her anchor. To round her in the ordinary manner would not stop her way, until the anchor be let go, in which case, before she could get away from it, in all probability there would be a sufficient quantity of the cable paid upon the top of it to insure its coming up upside down; the helm, therefore, must be put hard up when the anchor is let go, and if the tide be weak, the port-staysail-sheet hauled aft, when she will shear away from her anchor, and drop as nearly astream of it as the strength of the tide will permit. The helm, of course, must be afterwards eased, that she may not have too broad a shear.

If, with the like wind, it be required to ride to windward, the starboard anchor will be best. Furl all the square-sails, and come-to with only fore-and-aft sails set. Put the helm down, and keeping the staysails set after the anchor is gone will shear the ship to windward, the strength of the wind and tide determining how much canvas is requisite for the purpose—more, of course, in light winds and neap tide than when both are stronger—the staysails also requiring to be kept set if she will not keep a taut cable without them.

In coming-to upon a strong lee-tide with a fresh breeze, where there is a risk of snapping the chain or endangering the windlass by rounding-to, and bringing her up with stern way, the jerk may be very considerably eased by wearing round and putting the helm up when the anchor is let go. By these means a good scope of chain is laid in the mud, through which she must drag it before she can bring much strain on the windlass, and considerably ease the surges consequent upon bringing up when astream of the anchor with much stern-way.

Riding at Anchor in a Gale of Wind.—Vessels when riding in a roadstead in a gale frequently have their windlasses torn to pieces through the chain tightening and then slackening, as the vessel is drawn ahead or drops astern. The following plan has strong recommendations, as affording support to the windlass:—Reeve a good luff-tackle, and hook the single block on to the chain close to the windlass on the fore part, the double block being hooked to a toggle in the hawse-pipe, and hove well taut. Another tackle is then put on the chain abaft the windlass, and hove taut also. The one tackle acting against the other will keep the chain always tight round the windlass, and consequently prevent the great surging so trying to a windlass and a ship.

Keeping Watch.—The officer, when relieved, should point out to his successor the bearings of lights or any objects in view, give him the soundings alongside, the time at which the ship is expected to swing if in a tide-way, how the cable grows, as well as any order or direction that may be passed as to tending the ship. The deep-sea lead should be kept over the side, and the soundings tried frequently, and the bearings of the lights or other objects taken repeatedly. He should enter in the night order-book, as well as on the log-slate, the bearing of the different lights and soundings when he leaves the deck, signing his name to the same at the time; and he who relieves him should see that these entries agree with his own observation. He should look at the cable occasionally, and see how it grows, and also see that the spare anchor is ready for letting go, and chain clear for running.

Relieving the Watch at Sea.—Having received the course, sail

set, account of weather, and orders for the night relative to reports or calling the captain, see that the quartermasters, in relieving each other, do not give up the wheel until the ship is steady on her course; that the wheel ropes are clear; and, if running before a gale, that the relieving tackles are hooked, and sufficiently overhauled to allow the helm going hard over either way—taking care that the blocks of the relieving tackles are placed so as not to be jammed under the tiller; that the life-buoys are clear for letting go, and boat's falls ready.

ON TAKING IN HEAVY WEIGHTS.

A Derrick.—A derrick is a single spar rounded off at the heel to set in a shoe (similar to a shear-leg); the upper end is made with shoulders or cleats, to stop the purchase-blocks from working down, also the guys. The derrick may be used for many purposes instead of shears to great advantage, especially on board of merchant ships when discharging, it being so easily swung from a perpendicular position to rake over the ship's side, the heel resting in its shoe, and the head canted in any position by the guys. Any kind of a purchase may be used at a derrick-head, but the most general is the single and double burton.

On the subject of providing means.—Few ships go to sea without a spare topmast, or a spar to make one, which spar is in every way calculated for a derrick, if it will make a topmast. The rigging—that is the various guys and ropes necessary to sustain it in its position, and the purchase-blocks for lifting the weight—may be secured to the spar any height above the deck to suit the particular purpose in hand, without either cutting the spar, or nailing on cleats; as, by a well-managed arrangement of lashings, all slipping or shifting of position may certainly be prevented. It is necessary to observe, as a general rule, that in supporting a yard, or derrick, or shears, the supporting guys should be attached to the yard or spar at the spot from which the weight is to be suspended.*

* "By examining the merits and character of a derrick, it will, no doubt, be found to possess advantages so numerous and valuable as to render it superior in every respect to a lower yard for the purpose of lifting a heavy weight. The main and principal advantages are, that it transfers the whole weight to the deck, which can be well supported by props below; it relieves all anxiety about the safety of the mast and yard; and it can be placed vertically, or at any angle most suitable to a particular case. It can be supported without any difficulty, either with or without the aid of a mast; it is very soon rigged and ready for use, and as quickly dismantled. These advantages are sufficiently numerous to recommend it for general use in all cases where strength is required."—*An Enquiry relative to various Important Points of Seamanship*, by Nicholas Tinmouth, Master Attendant, Woolwich Dockyard.

NOTE.—The more a derrick approaches a perpendicular position, the less will be the strain upon the guys.

SECURING LOWER YARDS.*—In hoisting in or out heavy weights by the lower yards, the more you consider them merely as outriggers, the better you will insure their safety. In whatever manner you guy your purchases out to the yard-arms, whether by blocks, thimbles, or lashings, be careful that the purchase pendants render well through them. The yards should be well topped up, good rolling tackles on the opposite side, and trusses well taut after the yards are laid; but should the yards be required for a continuance—as the main-yard is in hoisting in or out heavy guns—the pendant should then go over the lower cap and down on the opposite side of the deck, and be there well lashed to the top tackle bolt. The yard and masts should be covered with canvas sufficiently for cross-lashing the main-yard to the mast, after it is top up. It would be still advisable to have good rolling or yard tackle on the opposite side to the purchase.

TO GET HEAVY MACHINERY IN OR OUT.—Protect the side and decks with planks, and shore the beams well up in the between decks. If the machinery is heavy, the best plan is to cant the main-yard a little; untruss it, and pass a strong lashing round the main-yard and mast; then have a spare spar, with a piece of plank under the heel, for a shore from the deck, lashed to the yard, about a foot inside where the yard tackle comes. Over the main hatchway rig a pair of shears, securing them with guys to the fore and mainmast-heads, and putting planks under their heels, which should be on the beam before the main hatchway. According to the size of the shears and strength of purchase, almost any weight may be lifted out in this manner; and it is recommended, when getting heavy machinery in or out, to use the yard tackle over the hatchway as well as the other in case of accident; and in lowering over the side, use the tackle on the shears to lower with, as well as the yard tackle.

ACCIDENTS.

THE BOWSPRIT SPRUNG.—Fish it with spare spars, and send down the fore-topgallant and royal-mast, and take the flying jib-boom in, to ease it as much as possible.

BOWSPRIT CARRIED AWAY.—Hard up the helm, shiver the after yards, and get the ship before the wind; take the foretopmast breast back-

* From *Professional Recollections*, by Captain Liadert, R.N.

stays forward over the topsail-yards, hook the pendant-tackles and set them up to the cat-heads, clap a tackle on to the forestay and set it up to the knight-heads; unreeve the maintopmast and spring-stays and set them up to the foretopsail-sheet bits; hitch a hawser to the foretopmast-head, take this in through one of the hawse-holes and set it up to the bitts of the windlass. While this is being done, reduce the sail, send down topgallant-yards and masts if they are aloft, and clear the wreck; rig a jury-bowsprit of a spare main-topmast, or a jib-boom.

The Cap on the Mast-head Worked Loose.—Make wedges and wedge it tight again; if this cannot be done, put a good lashing round the topmast and mast-head.

The Trestle-trees Carried Away.—Reeve as stout a rope as the sheave-hole will permit through it, splice a thimble in both ends, and set it up as tight as possible to the eye-bolts in the cap, or to the cap itself.

Main-yard Sprung in the Slings.—Take a couple of studdingsail-booms and cut each of them in two halves, lengthways; put these four halves round the yard and fish it.

The Parral of Topgallant-yard Carried Away.—In such a case, much of the whole force and weight of the yard and sail are thrown on the mast-head, and the topgallant-mast is endangered by it. If the ship is by the wind, brace the topgallant-sail aback immediately, and lower it at the same time; but if before the wind, immediately brace by and lower the topgallant-yard. Great care must be taken that the topgallant-sheets are not started, as that would much endanger the mast by the sail forcing itself against, and perhaps entangling itself round, the topgallant-stay.

Parral of the Maintopsail-yard Carried Away.—A topsail-yard parral may be repaired in the same manner, if carried away in moderate weather; but if blowing hard, with double or close-reefed topsails, the returning weight of the topsail-yard, and force of the sail when thrown aback, might endanger the mast, yard, or lee-topmast rigging; as however taut the weather topsail-brace may be when the parral is carried away, and the ship by the wind, the yard will surge over to leeward, and thereby allow the yard to swing far from the mast. In such a case, instantly man the down-haul tackle and weather clewline, and haul the yard down until the lifts are taut, so that the yard might then be squared, and the parral repaired.

Note.—Tho following is recommended by an excellent seaman:—In either case, first spill the sail, without its flapping; unbend the clewlines from the clews: if topgallant-sail, make the ends fast on the after trestle-trees; if a topsail, lash the clewline blocks on the after part of the topmast cap crossed; clew down the yard (with help of braces); secure the yard parral afresh.

THE WEATHER MAINTOPSAIL-BRACE GIVEN WAY—HOW TO GET THE YARD DOWN.—Ease the lee-sheet, to spill the sail; luff the ship to the wind, and lower away the halyards.

THE LOWER-BRACE CARRIED AWAY.—Lower the topsail, letting fly the lee-sheet, and hauling in the weather-braces, if needful; ease off the sheet of the course (short of spilling the sail), and let go the tack; for the first important duty is to save the yard.* If this accident occurs forward, have the weather-helm attended to.

TOPSAIL-BRACE AND PARRAL CARRIED AWAY.—If the weather-brace should be carried away when the parral goes, and the weather yard-arm flies far forward, it will then be advisable to put the helm up, and bring the wind on the opposite quarter, keeping the yards braced up, as before, on the mast to which the accident has happened (see *Carrying Away Topsail-parral*); and steer the ship so as to let the wind blow along the sail of the disabled yard, until it gently returns to the mast. When done, lash the yard on each quarter to the topsail rigging, and the topsail tye-blocks well round the mast; then fit the weather-brace and parral.

NOTE.—Too much care cannot be taken in keeping fast the topsail sheets, as upon that will depend much of the safety of the mast, yard, and rigging, as the heavy flapping of a topsail will be likely to shake everything to pieces.

TOPGALLANT-BRACE AND PARRAL CARRIED AWAY.—Brace by the lower and topsail-yards, and, if necessary, sufficiently touch the ship with the helm to throw the topgallant-sail slightly aback.

"TO MAKE A TEMPORARY LOWER YARD.—When a lower yard is entirely carried away at sea, it is not uncommon to make a yard with the spare spars supplied to the ship. This is frequently done by bringing two studdingsail-booms end to end, which together makes up the length of the yard; then to scarf them by bringing the spare topsail and topgallant-yard in the middle, and other small spars, as topgallant studdingsail-booms, &c., to make up the form of the yard. When the different spars are so placed as to overrun each other in the best possible way, they are well woolded together, and the yard is formed.

The rolling of the ship makes it frequently difficult to keep the spars together till woolded, in which case it is better to lay any inferior pieces on the deck as skids, and fix the lower ends guyed to the side of the ship; by this means the different spars may be kept safe."

TOPSAIL-YARD CARRIED AWAY UNDER SAIL.—If a topsail-yard is sprung, or carried away, it will much assist in securing the sails for

* One scend might break the brace; the next would break the yard; but there would be just time enough for a quick, ready officer to start all the principal gear that would relieve the spar.

sending on deck if the clewline blocks are taken off the yard, and made fast to the foremost eye-bolts in the topmast cap; by this means you can walk your clewlines and buntlines up, unbend and sling the sail with the yard-burton. When the sail is out of the way it gives a better opportunity for sending the wreck on deck, and shifting the topsail-yard. In some ships the topsail-tyes are left sufficiently long for sending down the wreck of a topsail-yard; but the most approved, and perhaps the best, purchase for sending topsail-yards up or down, is a burton fitted for that express purpose; this purchase is very superior to the hawser formerly used, as it requires less men to shift a topsail yard: the yard is swayed up much smoother, and not liable to those sudden jerks which you sometimes cannot avoid with a heavy weight on a single rope. Since burtons have been used for this purpose, topsail yards are much easier shifted, and men's lives less endangered.

Bobstays Carried Away.—Bobstays are generally carried away when sailing by the wind, and mostly in rough weather; therefore, the instant it is known, the ship should be put before the wind; and should the bobstays be gone in the way of the cutwater, it will be very difficult to reeve new bobstays. The best way, perhaps, is to take a well-stretched messenger, or a few lengths of the stream chain cable, with which make a clove-hitch round the bowsprit as much outside the bobstay collars as possible; then take the ends through the inner hawse-holes, one on each side, heave them both well taut together, then secure them to the bitts or ring-bolts. When done, bring the ship to the wind until you can reeve your proper bobstays. If you use rope, of course you must have plenty of service in the way of the hawse-holes.

Topmast-stay Carried Away.—If obliged to run a hawser up to secure a topmast, the hawser should be taken round the topmast-head, then made fast so as to leave a collar for the topgallant-mast to go up or down through. A bowline knot is considered a very good way of making the collar of your temporary stay, securing the end well on the side of the collar on which it is bent.

Cutting Masts Away.—Always cut the lee-rigging away first, then the stays, and afterwards the weather rigging. If riding head to wind, cut away all the rigging on both sides, except the two foremost shrouds, then cut the stays and foremost shrouds together, and stand by for a run forward as the mast falls on either quarter.

Taken in a Squall.—A vigilant look-out will usually prevent you being taken by a squall in an unprepared state.

If taken in a squall with the wind on the beam, before it, or close-hauled, keep your luff, and lower away and clew up all as fast as you

can. In doing so the ship will be relieved, and the canvas got in better than if the helm had been put up.

But if taken in a squall with the wind abaft the beam, putting the helm up and running away from it, as well as shortening sail, will then be the readiest mode of easing a ship.

If caught in a squall with studdingsails set, the best plan is to let fly studdingsail-tacks and outer lower halyards, and get the spanker in, if set. By this means you will get command over the vessel, to keep her before the wind if requisite. In letting go royal and topgallant halyards in a squall, never start a sheet; even the topsail-halyards may be let go, and the yard will come down without the topgallant sheets being slacked. Many a sail is split by attempting to clew it up in a squall; whereas if the halyards only are let go, and the yards clewed down till the first burst of the squall is over, there would be little danger of losing anything. Letting go the halyards of square sails, of course, refers to a time when no studdingsails are set, as the studdingsail-halyards would prevent a yard from coming down; but if the squall is very severe, then the studdingsail-halyards should be let go, that the yard may come down, as it is better to lose a studdingsail than a topmast, and the studdingsails, after the squall is over, will generally be picked up across the stays.

On Beam Ends.—A vessel is usually thrown upon her beam ends by a sudden squall taking her when under a press of sail, and shifting the ballast. She must be righted, if possible, without cutting away the masts; for, besides sacrificing them, the object can seldom be accomplished in that way if the ballast and cargo have shifted. Carry a hawser from the lee quarter, with spars and other good stopwaters bent to it. As the ship drifts well to leeward, the hawser will bring her stern to the wind; but it may not cast her on the other side. If a spring can be got upon the hawser from the lee bow and hauled upon, and the stern-fast let go, this will bring the wind to act upon the flat part of the deck, and pay her stern off, and assist the spring, when the sails may be trimmed to help her in righting. If she can be brought head to the wind, and the sails be taken aback, she may cast on the other tack. When there is anchoring ground, the practice is to let go the lee anchor, which may take the sails aback and cast her. Then the ballast and cargo may be righted.

If there is no anchoring ground, a vessel may still be kept head to the wind by paying a chain cable out of the lee hawse-pipe; or by bending a hawser to a large spar, which may be kept broadside to by a span, to the centre of which the hawser is bent. The same operation may be applied to a vessel overset, and is preferable to wearing by a hawser.

Make fast the hawser forward to the lee bow, carry the other end aft to windward, and bend it to the spar, and launch the spar overboard. By this means, or by letting go an anchor though there be no bottom to be reached, a vessel may often be recovered.

Ship on Shore—To Take Bower Anchor and Sixty Fathoms of Chain Out.—Run a kedge and a good hawser away, making a guess warp of it; get the long-boat under the bows, and lower away the anchor by the cat-fall. Pass a slip-rope round the shank of the anchor, having the standing part fast round the thwarts and through the ring; then get as much chain in the boat as she can conveniently carry, and haul out the long-boat by the hawser, veering out chain from the ship until enough; then veer away, and let go.

Note.—Precaution will, of course, be taken to have a good buoy-rope fast to the anchor flukes, in case it should be required to trip the anchor.

The Quickest Way to Trip an Anchor.—The quickest way to trip an anchor is by means of the buoy-rope, and, when the anchor is off the ground, heave the cable in by the ship. In case the buoy-rope should break, put luff-tackles on the cable in the boat.

To Take Out a Bower Anchor between two Boats.—If the long-boat is not capable of carrying the bower anchor and cable out, proceed as follows:—

Buoy a kedge and lay it out, with the whole warp attached, in the direction it is intended to haul the vessel off; and whilst this is being done, get as much of a bower cable as may be required payed from the vessel's quarter into the long-boat, leaving two or three fathoms in the bows of the boat to shackle to the anchor; the rest may be stowed in the middle of the boat. Have a piece of spar laid across the stern of the boat, and lashed for the chain to run over, or an old mat nailed over will do as well; fit good stoppers to the ring-bolt in the stern and after-thwart, that there may be no possibility of the chain running out of the long-boat faster than required.

Now, if the vessel has two quarter-boats, the bower anchor may be taken out between the two boats, thus:—

The sterns of the two boats should be as nearly square with each other as possible; a good strong spar (with its flat side down, and rounded at the upper part) should be laid across the gunwales of each boat before their centre; the spar should be well lashed to the nearest standing thwart and fore-and-aft rings, leaving sufficient room between the boats to admit of the flukes of the anchor going well between them, and the spar so lashed that neither boat could close or separate. The anchor should be lowered between the boats with the flukes perpendicular and the stock horizontal, thus dipping the flukes between the

boats, and securing the upper arm under the spar, each boat at the same time keeping her side of the anchor-stock square at her stern; the standing parts of the parbuckles or slip-ropes being made fast to the bottom rings, and the running parts rove through separate ones, if possible, and secured with several round turns round the after standing thwarts. Shackle the ends of the chain in the bows of the long-boat to the anchor, which must be well buoyed, and proceed to haul the two quarter-boats out by the warp, which can be done by hands in either boat, the long-boat following, and the cable being payed out as required. When the whole of the chain is laid out, hang the bight of the chain outside the long-boat by a slip-rope to the ring-bolt in the stern, and immediately the anchor is cut adrift from the small boats let go the slip-rope. In this way an anchor may be carried out with the greatest ease. The plan is extremely simple, and can do no injury to the boats, if common precaution be taken to have the stoppers in the long-boat fitted in such a way that the cable cannot go by the run; and as the cable should pass over the after-thwart, the stopper there will be found more useful, but it will be prudent to have two.

Provided the vessel has only one quarter-boat the same plan may be adopted, substituting the long-boat for the other quarter-boat, and placing, if necessary, a sufficient weight (in addition to the cable) to bring her gunwale on a level with the quarter-boat.

A Man Overboard at Sea.—If the ship be going free, and particularly if fast through the water, it is recommended to bring-to with the head-yards aback; for it is obvious, if the main-yard be left square, the ship will be longer coming-to, will shoot further, increase the distance from the man, and add materially to the delay of succour.

It will, however, require judgment, especially if blowing fresh, to be careful to right the helm in time, or the ship will fly-to too much, gain stern-way, and risk the boat in lowering down.

The best authorities recommend that, if possible, the ship should not only be hove aback when a man falls overboard, but she ought to be brought round on the other tack;* of course, sail ought to be shortened in stays, and the main-yard kept square. This implies the ship being

* When a man falls overboard in daylight, a hand should be sent aloft immediately to watch the spot where he is struggling, as it is in general just under the surface, which may be seen well from aloft, but found with difficulty from a boat. If going round gives a weather side for lowering a boat, do not do so, but throw all aback. Suppose her to be running with a strong breeze and studding-sails set, the tacks and outer lower-halyards should be let go, royal and topgallant-halyards, and weather head-braces; the yard will go forward as the vessel rounds-to, and the slack of the lee-braces can be taken in. Whilst this is being done, some hands will be getting the boat ready.

on a wind, or from the position of having the wind not above two points abaft the beam.

NOTE.—The great merit of such a method of proceeding is, that if the evolution succeeds, the ship, when round, will drift towards the man; and although there may be some small risk in lowering the boat from the ship while in stays, having at one period stern-way, there will, in fact, be little time lost if the boat be not lowered until the ship be well round, and the stern-way at an end. There is more mischief done generally by lowering the boat too soon, than by waiting until the fittest moment arrives for doing it coolly. It cannot be too often repeated, that almost the whole depends upon the self-possession of the officer of the deck. Unfortunately, there are circumstances under which no human aid can be given to any poor fellow falling overboard, such as heavy gales of wind when a boat will not live on the water; scudding when it is too dangerous to bring the ship to the wind, &c. In a case of this distressing nature, the life-buoy or spars may be thrown overboard in the hope of supporting the man, while the utmost endeavours should be made, by making sail and wearing, if there be any chance of placing the ship to windward and dropping down upon the man. In gales of wind, and the ship lying by the wind and barely forging ahead, men have often been saved by ropes and bights of ropes well disposed along the chains and quarters, and even by ropes well astern.

ON LEAKS.—On finding a vessel is leaky, the first step to be taken is to discover as nearly as possible the situation of the leak. To effect this, many plans have been suggested. The most practical of these appears to be,—first, to examine such accessible parts as are most likely to be defective, as the wooden ends forward and aft, the butts of the planks, and round the fastenings. Should no discovery of the leak be made, the ship must be tried before the wind, and on both tacks by the wind. If the leak increases before the wind, the leak is forward, probably in the wooded ends; if it decreases, it is in the stern; if the leak be greater on the starboard tack, then the leak is situated on the port side, and *vice versâ*. A leak in the bows, or on either side, may be lessoned by a thrummed sail being put over the part defective; but this mode is not applicable to the stern, as the vessel's way through the water would prevent its action. A leak situated much below the surface can only be stopped from the inside, except in the way named, of a thrummed sail—therefore the cargo in the neighbourhood of the leak must be removed, and the ceiling cut away so as to expose the part. Pieces of deal must then be made as nearly as can be of the shape of the room or rooms between the timbers, but so much less as to enable the pieces to be thickly covered with oakum, spun as for caulking; the pieces thus prepared should then be thoroughly tarred and put into the places where the leak is situated, and a piece or pieces of plank or spar bolted to the timbers to secure them in their situations. The force used in this operation must entirely depend upon the state of the outer plank and fastenings; for if, from the decay of the plank or timbers, the fastenings were to give way, the plank might be partially removed from the timbers, and the consequences fatal; but caulking may be done between the timbers and the pieces, and (but with more

care) between the upper and lower parts of the pieces and the outer planks; by these means the leak would be much lessened, even should it be situated in the plank and timber, and, if in the room, its communication with the vessel would be entirely cut off. This mode of treating leaks is evidently one adapted to those only of comparatively small dimensions; but it is applicable to such leaks, however situated, if approachable. If, from faulty caulking, the vessel be generally leaky the thrummed sail is the only remedy, and the pumps must be constantly and vigilantly attended and worked, to prevent injury to the cargo, and for the safety of the vessel and crew. The pressure of water at different depths is but very partially known to many seamen, and many have expressed the greatest surprise and doubt respecting the matter. First: water presses at its base and altitude; the hole or aperture admitting the water may be considered as the base, and the depth of the hole from the surface, the altitude. Second: the quantity of water admitted into any holes or apertures of the same dimensions will be as the square roots of those depths from the surface—that is, of such numbers as, multiplied together, would make such depths: thus, at 25 feet, five times as much water would be admitted as at one foot; at 16 feet, four times; at 9 feet, three times; at 4 feet, twice; and always in those proportions; but when the water has risen in the inside of the vessel, the quantities of water admitted will be as the difference of the square roots of the surfaces inside and outside. This circumstance will show that pumps which are not powerful enough to prevent the water rising in the hold to a certain height may be quite sufficient to prevent any further increase, and thus, with a cargo that water could not destroy, a ship might be safe with many feet water in her hold, and *ought not* to be abandoned. It is quite probable that want of information on this very important matter has caused the abandonment of may vessels that might have been saved. From what has been stated, it is plain that a leak situated near the bottom of a vessel is, independently of its being more difficult of access, more dangerous than one near the surface.—*Emerson's Useful Hints for Young Officers.*

A Sea Anchor.—This anchor may frequently be of the greatest possible use; it ought to be made in the following manner:—Take three spars, or topgallant or studdingsail-booms will be sufficiently large; with these spars form a triangle, the size you think will be large enough, when under water, to hold the ship; cut these spars to the required length before or after cross-lashing them well at each angle, so that they will bear an equal strain when in the water—but, should your spars be weak, you should always increase the number of your spars according to their weakness; fill up the centre of the triangle

with strong canvas, having eyelet-holes round its side about three inches, to which eyelet-holes attach the canvas well to the spars; at the back of the canvas pass many turns of an inch or inch and a half rope, net fashion, of course. A proper net would be preferable to rope so expended. To the base of the triangle attach a weight, or small anchor, supported in the centre of the base by a span running from each of the lower angles. To the first mentioned spans make fast the stream cable; when everything is quite ready, hoist it overboard, from the place you think it will answer best. There is every reason to believe, with this anchor under the trough of the sea and 70 or 80 fathoms of stream cable out, that a ship's drift would not be very great.* The plan proposed would be of the greatest advantage to dismasted vessels, and vessels which have lost their rudders, &c. If a vessel should approach the shore with this sea anchor down, it would enable her to bring-to with her proper anchors much easier than if the sea anchor had not been down. She might let go her proper anchors and veer from the sea anchor until she had sufficient cable out, which would give her a much better chance of holding. The sea anchor should have a buoy and a buoy-rope sufficiently long to go well under the trough of the sea.

Mode of Steering a Vessel which has Lost her Rudder.—The first thing to be done on losing a rudder is to bring the ship to the wind by bracing up the after yards. Meet her with the head-yards as she comes to. Take in sail forward and aft, and keep her hove-to by the sails. A vessel may be made to steer herself for a long time by carefully trimming the yards and slacking up the jib-sheets or the spanker-sheet a little, as may be required.

Having got the ship by the wind, get up a hawser, middle it, and take a slack clove-hitch at the centre. Get up a cable, reeve its end through this hitch, and pay the cable out over the taffrail. Having payed out about fifty fathoms, jamb the hitch and rack it well, so that it cannot slip; pay out on the cable until the hitch takes the water; then lash the cable to the centre of the taffrail; lash a spare spar under it across the stern, with a block well secured at each end, through

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* Capt. Liadert, R N., in his *Professional Recollections on Seamanship, &c.*, says he has twice tried a similar contrivance to that proposed above, and it answered beyond his expectations. "It appears preferable to riding by spars, as the spars drift so much faster than the sea anchor, from its being well under the trough of the sea, so makes great resistance to the drift of the vessel." The reason why the triangular form is proposed in preference to the square is, that the trough of the sea may strike as lightly as possible should the upper angles at any time approach the trough of the sea while riding at anchor. The square might certainly be so placed as to have one of its corners up in the same manner as the triangle, but then you would have the base in the very place you want the greatest resistance if you make a square.

which reeve the ends of the hawser, one on each quarter, and reeve them again through blocks at the sides, abreast of the wheel.

By this a ship may be steered until a temporary rudder can be constructed, which may be done thus :—

Let a spare topmast be cut to the required length of the rudder-stock, making the heel of the mast to answer for the rudder-head; use the remainder for the after part of the rudder, and leave a space near the lower end of the stock wherein to stow a quantity of shot, pig-iron, or the like, as ballast to assist in keeping the rudder end on. Plank it up on both sides with slabs or deals bolted or nailed to the main and after parts of the rudder, and let there be a strong shoe-piece bolted horizontally under all. Let the main piece have two mortice holes cut in it, one near the lower rudder-iron, the other about two-thirds up, through each of which pass a chain with a round turn, and carry the ends of these chains forward along the ships counter, so that their crossings may lie against or embrace the stern-post. Clap tackles on the ends of these chains, and bowse them taut forwards, in order to bind the rudder firmly against the stern-post. For greater security, also, the rudder may be hung by a rope or small chain passed through the fid-hole of the topmast, and made fast round a bar laid across the rudder-hole on deck. Bolt two spars to the upper end of the broad part of the rudder, one on each side, and lash them together in order to form a tiller projecting out from the rudder at an angle of elevation; make fast the tiller-ropes to its outer end, and lead them to the steering wheel.*

Let a spare topmast be cut the required length of the rudder, and take an iron band of sufficient size† for the lower end of the topmast to travel in: the band, if too large, can be woolded round, and should *always* be leathered to prevent chafe. Next, take a lower cap, and enlarge the square hole to fit into the stern-post; the round hole is for the *upper* part of the topmast to travel in. Take a jib-boom and cut it in two, or take other pieces of spar and bolt the pieces on abaft the topmast, after squaring the edges which are to come in contact with each other, and cutting a score in the forward part of the jib-boom or spar, next to the topmast, at the lower end where the iron band comes, so that the working of the rudder may not be impeded; plank the whole over with stout oak planks, slabs, or deals, according to materials, and

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* The above ingenious method for supplying a vessel with a temporary rudder, when an accident has befallen the original one, has been very justly recommended by the late Capt. Basil Hall, R.N. A description of a jury rudder for the Royal Navy, as per Admiralty Order of 28th January, 1839, will be found in Lieut. Jennings' *Hints on Sea Risks.*

† The iron band that goes round the main yard will answer the purpose.

bolt in a fish abaft all. A tiller can now be fitted. The band of iron for the heel of the rudder will require a chain on each side, to reach nearly to the fore-channels; and if the material be at hand, have two eye bolts in this band for the purpose of securing the chain to. Also have a small piece of iron plate nailed, to prevent the band from working upwards. At the fore-channels attach two tackles to the chains, to bind the iron band close to the stern-post. Have a kedge with a slip-rope to sink the rudder, which, being put over the side and brought to the rudder trunk; can easily be hauled into its place; haul the chains taut forward, one on each side; put the cap on; ship the tiller, and put a lashing on each side the rudder-head to the deck, to keep the rudder from lifting.*

A spare cap cut away at the after part, so as to fit the stern-post at the water's edge or a little below, may be used instead of the iron band as in the above plan; the topmast being passed through the round hole of the cap. To the topmast, which is the main piece of the rudder, will, of course, be bolted pieces of spar, so as to assume as much as possible the shape of a rudder, and pieces of plank will be nailed athwart it.

Also take an anchor-stock (wood), and square two of the edges; cut away a circular score in each, for them to join together round the topmast below the squares, and thus you have a substitute for an upper gudgeon; drive the anchor-stock hoop on the rudder-head to keep it from splitting. The rudder is kept close to the stern-post by shackling to the eye-bolts of the cap two chains with tackles on the end of them, one on each side, and taking them well forward. The fid-hole of the topmast must be enlarged to receive the tiller, if not already large enough.

NOTE.—" A ship might lose her rudder at a critical moment in crossing the bar of a river, when a few minutes more might run her aground if she were unmanageable: and, in this case, what temporary rudder is best becomes a question for which a few moments only are given to decide. The plan of steering by the stream cable payed out astern, or with the stern-boat lowered instantly, with the plug out, and towed astern by a hawser, with guys leading up to each quarter, would, perhaps, then be adopted; while a ship losing her rudder at sea would have leisure to adopt any other plan.

" It might be an advantage if every vessel would take some opportunity of trying how she could steer with a stern-boat in the manner described, and what length of towline was required to enable her to steer the most easily, so as to avoid wild yawing. The experiment might be made in moderate weather with the wind on the quarter, and also right aft, under topsails, topgallantsails, and foresails, running five or six knots. Nothing gives confidence so much as practice."—*The Kedge Anchor.* By W. Brady, U.S. Navy.

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* The above plan of a jury rudder was given me at Sheerness by a gentleman who many years ago constructed a rudder on this plan for a frigate of which he was carpenter. The plan is substantially the same as that given by Capt. Sedgwick, in *Golden Hints to Young Mariners*.

THE OFFICIAL LOG-BOOK.

THE Board of Trade sanctions forms of official log-books, which may be different for different classes of ships, so that each such form contains blanks for the entries after-mentioned, and an official log of every ship (except ships employed exclusively in trading between ports on the coast of the United Kingdom) must be kept in the appropriate sanctioned form; and this official log can, at the discretion of the master or owner, either be kept distinct from the ordinary ship's log, or united therewith,—so that, in all cases, all the blanks in the official log be duly filled. Every entry in every official log must be made as soon as possible after the occurrence to which it relates, and, if not made on the same day as the occurrence to which it relates, must be made and dated so as to show the date of the occurrence and of the entry respecting it, and in no case must any entry therein in respect of any occurrence happening previously to the arrival of the ship at her final port of discharge, be made more than twenty-four hours after that arrival.

Every master of a ship, for which an official log-book is required by the Act, must make or cause to be made therein, entries of the following matters:—

1. Every legal conviction of any member of his crew, and the punishment inflicted.

2. Every offence committed by any member of his crew, for which it is intended to prosecute, or to enforce a forfeiture, or to exact a fine; together with such statement concerning the reading over such entry, and concerning the reply (if any) made to the charge as required by sec. 244.

3. Every offence for which punishment is inflicted on board, and the punishment inflicted.

4. A statement of the conduct, character, and qualification of each of his crew, or a statement that he declines given an opinion on such particulars.

5. Every case of illness or injury happening to any member of the crew, with the nature thereof, and the medical treatment adopted, (if any).

6. Every case of death happening on board, and of the cause thereof.

7. Every birth happening on board, with the sex of the infant and the names of the parents.

8. Every marriage taking place on board, with the names and ages of the parties.

9. The names of every seaman or apprentice who ceases to be a member of the crew, otherwise than by death, with the place, time, manner, and cause thereof.

10. The amount of wages due to any seaman who enters her Majesty's service during the voyage.

11. The wages due to any seaman or apprentice who dies during the voyage, and the gross amount of all deductions to be made therefrom.

12. The sale of the effects of any seaman or apprentice who dies during the voyage, including a statement of each article sold, and of the sum received for it.

13. Every collision with any other ship, and the circumstances under which the same has occurred (sec. 282).

In the case of foreign-going ships, the master must, within forty-eight hours after the ship's arrival at her final port of destination in the United Kingdom, or upon the discharge of the crew, whichever first happens, deliver to the Shipping Master before whom the crew is discharged, the Official Log-book of the voyage.

The entries hereby required to be made in official log-books shall be signed as follows: that is to say, every such entry shall be signed by the master and by the mate, or some other of the crew; and every entry of illness, injury, or death, shall also be signed by the surgeon or medical practitioner on board (if any); and every entry of wages due to, or of the sale of the effects of any seaman or apprentice who dies, shall be signed by the master and by the mate, and some other member of the crew; and every entry of wages due to any seaman who enters her Majesty's service shall be signed by the master and by the seaman, or by the officer authorised to receive the seaman into such service.

LEADING LIGHTS IN THE ENGLISH CHANNEL.

ON THE ENGLISH COAST.

Bishop Rock—Scilly Isles—One fixed light.
Hidden between the bearings of S. W. by W., and W. by N. ¼ N.

St. Agnes—Scilly Isles—One revolving light, every minute.

Seven Stones—Light vessel, in 40 fathoms—Two fixed lights.

Longships—One fixed light.

Wolf—(Building).
N.B. ¾ of a mile E. by N. is frequently a vessel moored, with a light.

Lizard—Two fixed lights.
When in one, these lights keep clear of the Manacles to the *eastward;* and of the Wolf to the *westward.*

Eddystone—One fixed light.

Start Point—One fixed and flashing light, every minute.
In the same tower is shown a Fixed light in the direction of Berry Head, visible only when the Start Point bears between W. ¼ S. and S.W. by S.; also a faint continuous light is seen within 10 miles.

Portland—near the Bill—Two fixed lights.
When in one, they lead between the Race and Shambles.

Shambles—Light vessel, on east end of shoal in 15 fathoms—One fixed light.

Needles—Isle of Wight—One fixed light.
Red from N.W. ½ N. round Westward to S.W. by W., except between East and E.S.E., when it will appear as a *White* light; it also appears *White* from N.E. by E. to N.E. by E. ½ E.

St. Catherine—Isle of Wight—One fixed light.

Bembridge, or Nab—Light vessel, in 5 fathoms—Two fixed lights.

Owers—Light vessel, in 19 fathoms—One fixed light.

Beachy Head—One revolving light, every two minutes.
Kept open of the next Eastern Cliff, leads outside the Royal Sovereign, and other shoals. *Note the difference between this light and that on Cape Grisnez, which flashes every half minute.*

Dungeness—One fixed light.

Varne Shoal—Light vessel, in 16 fathoms—One revolving light, every 20 seconds

South Foreland—Two fixed lights.
These lights in one clear the South end of the Goodwin Sands.

South Sand Head—Light vessel, in 13 fathoms—One fixed light.

Gull Stream—Light vessel, near west edge of sand, in 8½ fathoms—One revolving light, every 20 seconds.

North Sand Head—Light vessel, off north end of the sand, in 9 fathoms—Three fixed lights, triangular.

North Foreland—One fixed light.
Shows a band of *Red* light to clear the East end of Margate Sand, a cable's length, when bearing S. by E. ½ E. to S. ½ W.

ON THE FRENCH COAST.

Ushant—N.E. point of Island—One revolving light, every 20 seconds. Lat. 48° 28′ N., Long. 5° 3′ W.

Ile Vierge—One fixed and flashing light, every 4 minutes a Red flash; the Red flash is preceded and followed by a short eclipse, which does not appear total within the distance of 6 miles.

Ile de Bas—One revolving light, every minute; the eclipses do not appear total within the distance of 12 miles.

Sept Isles—One fixed and flashing light, flash every 3 minutes.

Heaux de Brehat—One fixed light.

Cape Frehel—One revolving light, every half minute; eclipses not total within the distance of 12 miles.

Granville—One fixed light

Chausey Islands—One fixed and flashing light, Red flash every 4 minutes; eclipses not total within the distance of 6 miles.

Carteret—One revolving light, every half minute; eclipses not total within the distance of 6 miles.

Hanois Rock—One revolving light, every 45 seconds; Red light visible all round the western horizon.

Casquets—Opposite Bill of Portland—Three revolving lights, every 20 seconds.
Relative position E. ¾ N., S.W. ¾ W., and N.W. ¾ W.

Cape de la Hague—One fixed light.

Barfleur—One revolving light, every half minute; does not quite disappear within the distance of 12 miles.

Point de Ver—One fixed and flashing light, flash every 4 minutes; eclipse not total within 6 miles.

La Heve—Two fixed lights.

Fecamp—One fixed light.

Ailly—One revolving light, every minute; eclipses not total within 10 miles.

Alpreck—One fixed and flashing light, every 2 minutes a Red flash; flash preceded and followed by a short eclipse.

Cape Grisnez—Opposite Dungeness—One revolving light, every half minute; eclipses not total within 12 miles.

EAST COAST OF ENGLAND AND SCOTLAND.

Kentish Knock—Light vessel—One revolving light, every minute.
On the E. side of the Sand, in 12 fathoms.

Galloper—Light vessel—Two fixed lights.
On S.W. part of Shoal, in 20 fathoms.

Sunk—Light vessel—One fixed light.
Fairway of East Swin, in 10 fathoms.

Shipwash—Light vessel—One fixed light.
Off N.E. end of Sand, in 9½ fathoms.

Orfordness—Two fixed lights.
When in one, S. of the Ness, they lead through Hollesley Bay, close to the N.W. edge of the Whiting, and across the outer edge of the Cutler Sand; and to the North, they lead inside of the Knoll, the Ridge, and the Napes.

Lowestoft—Two fixed lights.

Corton Channel—Light vessel—One revolving light, every 20 seconds a Red face.
Moored in 15 fathoms at S.E. entrance of Corton Gatway.

St. Nicholas—Light vessel—Two fixed lights.
At Northern extremity of Hewitt's Channel, one *Bright*, and one *Red*. The latter at the afterpart of the Lightvessel, 20 feet above the water.

Cockle—Light vessel—One revolving light every minute.
At North entrance, Eastern side, in 6½ fathoms.

Winterton—One fixed light.

Newarp—Light vessel—Three triangular fixed lights.
Near the North end of the Sand, in 19 fathoms.

Hasborough—Two fixed lights.
In one, they lead through Hasborough Gatway.

Hasborough—Light vessel—Two fixed lights.
Near North end of Sand, in 15 fathoms.

Leman and Ower—Light vessel—Two lights: upper light revolves every minute; lower, fixed.
Near the S.W. point of the Ower, but 5 miles S. of its shoalest spot, and 4 miles E.S.E. of the shoalest part of the Lemon.

Cromer—One revolving light, every minute.

Dudgeon—Light vessel—One fixed light.
Near the shoal, in 9 fathoms.

Outer Dowsing—Light vessel—One revolving light, Red face every 20 seconds.
On the western side of the sand in 9 fathoms.

Spurn—Light vessel—One revolving light every half minute.
Off the Point, River Humber, in 9 fathoms.

Spurn—on the Point—Two fixed lights.

Bull Sand—Light vessel—One fixed light.
S.E. end of Bull Sand, in 5½ fathoms.

Flambro' Head—One revolving light, every 2 minutes; two flashes Bright, one Red. When bearing N.N.E., clears north end of Smithic Shoal.

Whitby—Two bright fixed lights.
Towers, in a N. 19° W., and S. 19° E. direction, and when in *line* lead on Whitby Scar Rock, distant about two miles from the Northern Tower. The lights range from N. 28° W. round eastward to S. 17° E. They are visible at a distance of about 23 miles, and show over the N. cheek of Robin Hood's Bay. Mariners are to observe that the light from the Northern Tower is coloured Red from the line of bearing of the Whitby Scar Rock, to the in shore bearing of N. 28° W.

Hartlepool—on the Heugh—Two fixed lights in one tower: high light, Bright; low light, Red.
Upper light all night; small lower light, from half flood to half ebb.

Sunderland—North Pier Head—Two fixed lights in one tower.

Sunderland—South Pier Head—One fixed light.
The lower light on North Pier Head is a small (distinguishing) Red light, 18 feet below the upper light; and both are exhibited all night. South Pier Light exhibited from half flood to first quarter ebb.

Tynemouth—One revolving light, every minute.

Coquet—S.W. part of the Island—One fixed light, Bright.
Brilliant when seen from the Eastward, between S. by W. ½ W., and N. by E ½ E. A dim light is seen round the remainder of the circle. When seen in the direction of Hauxley Point Buoy, it appears Red; and to avoid the Boulmer Rocks, a Red light is shown in that direction.

Farn—Two lights: highest revolving every half minute; lowest, fixed.
Highest light, near S.W. point of the Island; lowest near its N.W. point. The low light is only seen in a Northerly direction. They bear from each other N. by W. ½ W., and S. by E. ½ E. High light open rather less than its own height E. of low light, leads between Megstone and Oxscar. These lights, and Megstone in one, lead between Ploughseat and Goldstone.

Longstone—One revolving light, every half minute.

St. Abb's Head—One flashing light, flashes every 10 seconds.

Inchkeith—on the summit of the Island—One revolving light, every minute.

Isle of May—on the summit of the Isle—Two fixed lights.

When in one, bearing S.S.W. ¼ W., and N.N.E. ¼ E., they lead about half-a-mile to the Eastward of the North Carr Rock. The lights must on no account be opened to the Westward.

Bell Rock—One revolving light, every 2 minutes; Bright and Red alternately.

Buddonness, or Tay—on the Ness—Two fixed lights.

Bearing N.N.W. ¾ W., and S.S.E. ¾ E. Leading lights between the Gaa and Abertay Sands, at the mouth of the river Tay.

Girdleness—on the Ness—Two fixed lights

Vertical, in the same tower. Seen from N.N.E. to W.S.W. ½ W. by the Eastward.

Buchanness—on the Ness—One flashing light, flashes every 5 seconds.

Visible from N. by E. to S.W. by W., by the Eastward.

Kinnaird Head—on the Head—One fixed light.

Shows Red N.N.W. ½ W., and northerly as far as the land admits. Visible from W.N.W. to S.S.E. ¾ E. Northerly and Easterly.

Covesea Skerries—on Craig Head—One revolving light, every minute.

Visible from W. by N. ¼ N., round Northerly and Easterly, to S.E. by E. ¼ E., Bright; but from S.E. by E. ¼ E. southerly to S.E. ¼ S., Red.

Tarbetness—on the Ness—One intermittent light.

Visible 2½ minutes, then suddenly eclipsed half a minute. But to the Westward of the Ness, the light is permanently visible.

Noss Head—on the Head—One revolving light, every half minute; Bright to seaward and Red towards Sinclair Bay

Visible from W.N.W. to S.W. ¼ W., by the Eastward.

Pentland Skerries—on the Island—Two fixed lights.

Bearing N.N.E. and S.S.W.

Dunnet Head—on the Head—One fixed light.

Visible from S.E. ½ E. to W. by N. ½ N. by the North.

Holburn Head—One flashing light, every 10 seconds.

Cantick Head—Orkney Islands—One revolving light, every minute.

Hoy—Orkney Islands—Two fixed lights.

The high light stands on the N.E. point of Gremsa Island; and the low light on its N.W. point. High light, Red from Seaward, but White when between S.S.E. ¼ E., and W.S.W.; it also lights a small arc towards Cava, in Scapa Flow, between N. ½ W., and N.N.W. ½ W. The low light, White, is visible between E. ½ S. and W. ½ N. round by N. When the lights are in one, they lead between the rocks of Bow and Kirk; when within half-a-mile of the shore on this line, the high light disappears below the foreground, and it is then time to haul towards the Stromness shore, when the Red light will re-appear.

Start Point—on the East Point of Sanday Island—One fixed light.

North Ronaldsha—on the North Point—One flashing light, flashes every 10 seconds.

Sumburgh Head—on the S.W. Point of the Shetlands—One fixed light.

Visible from N.E. by E. ¼ E., round to N.W. by N. ¼ N. by the Southward.

Cape Wrath—on the Cape, N.W. Point of Scotland—One revolving light, every 2 minutes; Bright and Red alternately

Visible from S. ½ E. to S.W. by W., by the N.

Butt of Lewis—N. Point—One fixed light.

Barra Head—highest part of Bernera Island, S. Point of Hebrides—One intermittent light.

White 2½ minutes, then dark ½ minute, visible from N. by E. to E.N.E., by W. and S.

Skerryvore—on the Rock, 12 miles W.S.W. from Tyree Island—One revolving light, every minute.

LEADING LIGHTS OF ST. GEORGE'S CHANNEL.

COAST OF IRELAND.

Fastnet—on the summit of the Rock—One revolving light, every 2 minutes; visible 18 miles.

This is instead of that formerly shown on Cape Clear. There is a dangerous rock, carrying only 11 feet at low water, 400 yards N.E. by E. of the Fastnet.

Kinsale—on S. Point of the Old Head—One fixed light, visible 21 miles.

Red light is shown in a line to the Horse Rock, in Courtmacsherry Bay; Bright to Seaward.

Cork Harbour, or Queenstown—on Roche Point, E. side of entrance—One revolving light, visible 14 miles.

Red, towards the sea; towards the harbour, Bright.

Ballycotton—on the Outer Island—One flashing light, every 10 seconds; visible 18 miles.

Seen from E. ½ N., round Southerly, to W. ½ N. There are red panes of glass at the foot of the apparatus, to warn vessels not to approach within that mark. When visible, tack off shore.

Minehead—S. side of Head—One intermittent light, every minute.
Bright 50 seconds; suddenly eclipsed 10 seconds. Seen from E.N.E. ½ N. to W. ¾ S., and visible 21 miles.

Waterford—Hook Tower, E. side of entrance—One fixed light, visible 16 miles.

Saltees—Light vessel—Two fixed lights, visible 9 miles.
Off Coningbeg Rock, the southernmost of the Saltees Islands, in 32 fathoms.

Tuskar—on the Rock—One revolving light every 2 minutes; visible 15 miles; two sides Bright, one Red.
Red light seen 10 miles, and visible every sixth minute.

Blackwater Bank—Light vessel—One fixed light, visible 9 miles.
In 19 fathoms, off N.E. part of Bank.

Arklow—Light vessel—One revolving light, every minute; visible 10 miles.
Moored South end of the Bank, in 22 fathoms.

Wicklow—on the Head—Two fixed lights, visible 21 and 16 miles.
When in one, they lead between the India and Arklow Banks.

DUBLIN BAY:—

Kish—Light vessel—Three fixed lights, in a triangular form; visible 10 miles.
Moored off N. point of Kish Bank.

Poolbeg—Two fixed lights in one tower, visible 12 miles.
At the end of S. Wall, at the entrance to the river Liffy. The lower light is shown from half flood to half ebb. The lower light is much fainter than the upper one.

Poolbeg—One fixed light, visible 10 miles.
At the end of the N. Wall or Quay.

Bailey—on S.E. Point of Howth Peninsula —One fixed light, visible 15 miles.

Howth—on E. Pier Head—One fixed Red light, visible 11 miles.

Rockabill—One flashing light, every 12 seconds; White flash between N. ½ W. and S.W. by S.; Red flash towards land.

Carlingford—on Haulbowline Rock—Two fixed lights in the same tower, visible 15 miles.
The lower light from half flood to half ebb.

Dundrum Bay—on St. John's Point—One intermittent light, every minute; visible 12 miles.
The light is Red for 45 seconds; suddenly eclipsed for 15 seconds.

South Rock—on the Rock—One revolving light, every minute and a half; visible 12 miles.

Copeland—on small Copeland Island—One fixed light, visible 16 miles.

Maidens—on the Rocks—Two fixed lights, visible 13 and 14 miles.

Rathlin—on N.E. Point of Island—Two lights in same tower; the upper light revolving every minute, giving a Bright light during 50 seconds, then eclipsed for 10 seconds. The lower light, fixed.
The upper light visible from seaward, between the bearings of S.E. ½ S., round by the Eastward, to N.E. by N.; and in the channel Westward of Rathlin Island, from E.N.E. ½ N. to E. ¼ N., and is coloured Red on the line of the Carickavanan Rock. Visible in clear weather 21 miles. The lower light is a separate light within the distance of 10 miles, and from seaward between the bearings of S.E. by S., and N.N.E ½ E., and not visible in the channel Westward of Rathlin Island.

Innishowen—on Dunagree Point—Two fixed lights.

Innistrahul—on N.E. part of the Island—One revolving light, every 2½ minutes; visible 18 miles.

Lough Swilly—on Fanad Point—One fixed light, Red; but towards the Lough, Bright; visible 14 miles.

Tory Island—on N.W. part of the Island —One fixed light, visible 16 miles.
To vessels passing to the S.E. of the Island, the light will disappear behind its heights, between N.W. by N., and N.W. ½ W.

Rathlin-o'-Birne—on the Island—One fixed White light, visible 16 miles; Red towards the mainland and Sound, Eastward of the Island.

Aranmore Island—(Building.)

WELSH AND SCOTCH COASTS, INCLUDING THE ISLE OF MAN.

Smalls—on the Rock—One fixed light, visible 15 miles.

South Bishop—on the Rock—One revolving light, every 20 seconds; visible 18 miles.

Cardigan Bay—Light vessel, between South Bishop and Bardsey Island—One Red revolving light, every 30 seconds, when it appears brightest.

Bardsey—on the Island—One fixed light, visible 17 miles.

Stack—on South Stack Rock, off N.W. Point of Holyhead Island—One revolving light, every 2 minutes; visible 19 miles.
During foggy weather, a small Bright light revolving in 1½ minute is occasionally shown about 40 feet above the sea, and 30 yards North of the main lighthouse.

Skerries—on the highest Island—One fixed light, visible 16 miles.

A Red gleam shown over the Coal Rock to E. ½ S.

Lynus—on the Point—One flashing light, in 10 seconds; visible 8 and obscured 2 seconds; seen 16 miles.

ENTRANCE TO MERSEY AND DEE RIVERS:—

Air—on the Point, at low-water mark—One fixed light.

From N.W. to W. it shows bright; from N.W. Northerly, to E. by S. ½ S., Red; from E. by S. ½ S. to S. by E., Bright. The Red light is visible only within the Hoyle Sand. A Bell is sounded in foggy weather.

Liverpool North-West Light Ship—One revolving light, every minute.

Off the W. extreme of the 3 and 4 fathom Tongue in 6½ fathoms.

Hoylake—near the Church—Two fixed lights.

When in one S.W. by S., you may haul up the Rock Channel.

Bidston—on Bidston Hill—One fixed light visible 23 miles.

Leasowe—One fixed light, visible 15 miles.

On the shore midway between the Mersey and Dee Rivers.

Rock—One revolving light, every minute; visible 14 miles.

On the point W. Side of the river Mersey. This light is bright for two minutes, then Red the third minute. A Fixed light shows down the Rock Channel and up the river, when 11 feet water.

Crosby—Light vessel—One fixed Yellow light, visible 8 miles.

Crosby Channel, N.E. elbow of Great Burbo Bank. Moored in 44 feet at low water.

Crosby—near Crosby Point—One fixed light, visible 12 miles.

Formby—Light vessel—One fixed Red Light, visible 8 miles.

At the point of meeting of the Crosby and Queen's Channels. Moored in 25 feet.

Great Orme Head—One fixed light, visible 24 miles.

White between S.E. by E. ¾ E. by the South to West; Red from W. to W. ¾ N.

ISLE OF MAN:—

Ayre—¼ mile S.W. of the Point—One revolving light, every 2 minutes; Bright and Red alternately. Visible 15 miles from S. by W. North-easterly to W. by N.

Calf of Man—W. side of Calf Island—Two revolving lights, every 2 minutes; visible 24 and 22 miles: high light visible from E.N.E. to S.E. by E., by the Westward.

When in one, they lead on the Chicken Rock.

Douglas—on the Head—One fixed light, visible 14 miles.

Not visible from Lang Ness, but with three miles' offing, it will be seen N.E. ½. E.. and the Calf light at the same time N.W. by W. ½ W.

Bahama Bank—Light vessel, a mile off the S.E. tail of the Shoal, in 11 fathoms—Two fixed lights, visible 10 miles.

Mull of Galloway—on S. Point—One intermittent light, every 3 minutes; visible 2½ minutes, and half minute eclipsed. Visible 23 miles from N.E. to N.W. ½ W.

Corsewall—on the Point, W. side of entrance of Loch Ryan—One revolving light, every 2 minutes; Bright and Red alternately: visible 15 miles from N.E. by E., Northerly, to S.W.

Sanda Island—on Ship Rock—One fixed Red light.

Pladda Island—on S.E. Point of Arran Island—Two fixed lights, vertical; visible 17 and 14 miles, from N.W. by W., Southerly, to N.E. by E.

Davar Island—on Eastern part—One revolving light, every 30 seconds; visible 17 miles, from N. ½ W. to E. by S., by the North.

Clyde River—Cumbræ, on W. side of Little Cumbræ—One fixed light, visible 15 miles.

Mull of Cantyre—on S.W. headland of Cantyre—One fixed light.

Rhynns of Islay—on Oversay Island, off S.W. Point of Islay—One flashing light every 5 seconds.

LEADING LIGHTS OF THE BRISTOL CHANNEL.

Trevose Head—on N.W. part—Two fixed lights, visible 19 miles. The lower light is 50 feet in advance of the higher one. Lat. 50° 33′ N., long 5° 1½′ W.

Lundy—on the ridge of the Island—Two lights in one tower; upper, revolving every 2 minutes; lower, fixed, and visible 30 miles.

Low light only visible from the Westward, between N.N.W. and W.S.W.

Flatholm—on the Island, S. Point—One fixed light, and visible 17 miles.

English and Welsh Grounds—Light vessel —One revolving light, every minute, and visible 10 miles.

Moored S. side of Bristol Channel, in 6 fathoms

Usk—W. side of entrance of the river— Two fixed lights, and visible 10 miles.

A Red light in this tower, 20 feet below the Bright light, leads into the River on a N. by W. ½ W. bearing, between a Black and White Buoy, two cables apart, at the entrance and 1¼ mile from the tower, which bears from the Western or Black Buoy, N. by W., and from the Eastern one N.N.W. Another Red light is also shown up the river, in a N.E. direction, towards Newport, elevated 39 feet.

Nash—on the Point—Two fixed lights, visible 18 and 16 miles.

The lights in one, N.W. by W. ¼ W., lead a cable's length S. of Nash Sand

Mumbles—on the Head—A fixed light, and visible 15 miles.

Scarweather—Light vessel—One Red revolving light every 20 seconds.

Off the W. end of the sand. A half globe above usual globe.

Helwick—Light vessel—A light revolving every minute, and visible 10 miles.

Off West end of the Sand, in 16½ fathoms.

Caldy—on Caldy Island, S. part—A fixed light, and visible 19 miles.

St. Ann's—on St. Ann's point, Milford Haven—Two fixed lights, and visible 19 and 17 miles.

When in one, they lead clear of the Crow and Toes Rocks.

OBSERVATIONS RELATIVE TO ENTERING AND NAVIGATING THE ENGLISH CHANNEL.

When running for the Channel, the ground should invariably be sought for in good time; nor should the lead in any case be neglected after the ground has once been obtained, especially during the night; because in the parallel of 51° 10′ N. the same soundings will be found as at 10, 18, 28, and 43 leagues from Scilly. Nor is this identity confined to that latitude alone. By the above precaution, all the various alterations in depth, substance, and colour will be *progressively* unfolded while advancing to the eastward, and the parallel of latitude with greater facility preserved or regained if temporarily quitted.

Generally speaking, the water in the entrance of the Channel is from 8 to 10 fathoms deeper towards the French coast than towards the English. The soundings, too, are coarser; the stones are larger; and the different substances altogether more loose and unconnected, and the compound of a paler colour than on the northern side of the Channel.

The Best Parallel for entering the Channel is between 49° 15′ and 49° 25′, according to the inclination of the wind; because it is between those limits that the relative situation of your vessel can with the greatest certainty be ascertained, as well in respect to depth of water as to quality of ground (alluding to the discrimination between oaze and sand), and which cannot be so well defined in any other latitude,

The keeping on this parallel is rendered still more necessary, in consequence of the rotary motion and northerly inclination of the tide to the westward, south-westward, and southward of Scilly.

Between the parallels of 49° 15′ and 49° 25′ N., the edge of the bank of soundings will be found in the longitude of 11° 18′ W. Here the depths of water will be from 270 to 335 fathoms, and the ground a mixture of sand and dark-greenish oaze. From hence, as you proceed towards the Channel, you will find sand and oaze for 16 leagues further eastward, the depths decreasing very suddenly from 81 and 80 fathoms to 71 and 69, and the ground changing to coarse and fine reddish-yellow sand and shingle.

On the Parallel of Fastnet Rock, or that of 51° 23′ N. and in 11° 34′ W., are 286 fathoms water, the ground a sort of fine dark viscous brown sand; this is the edge of the bank. Thence, as you proceed eastward, the depths decrease very suddenly. In the longitude of 11°, are 96 fathoms, very fine dark sand; from hence to the longitude of 10° 30′, the depths decrease more gradually—viz., about 4 fathoms every 5 miles—but again decrease very suddenly until within 5½ leagues of the land. Seven leagues westward of the Mizen Head, there are 60 fathoms, oazy ground; and not further off than 10 leagues, 80 fathoms will be found—the bottom oaze, as before.

On the Parallel of Trevose Head.—Vessels running for the Bristol Channel, and bound into the Severn from the Atlantic, should endeavour to preserve the parallel of Trevose Head, or that of 50° 30′, not only with a view of counteracting the north-westerly and northerly excess of tide which prevails in the Irish Channel, but because the soundings, on approaching it, decrease gradually, and because this promontory projects a considerable distance to the westward beyond the general direction of the Cornish coast. The land, also, being very high and steep, renders it the most eligible spot for a landfall between the Land's End and Hartland Point, from whence a vessel may with confidence shape a course for the Bristol Channel. On this parallel, and in the longitude of 10° 53′, are 140 fathoms, fine dark-brown sand; this appears to be the edge of the bank of soundings in that latitude. From hence, the transition to shoal water is very sudden, as 13 miles further eastward are only 94 fathoms. This depth is in the longitude of 10° 32′ W., and as you proceed easterly, the depths more gradually decrease. In longitude 9° 44′, are 71 fathoms, very fine dark-grey sand, of the consistency of beaten pepper; 7 leagues further eastward, are 71 and 69 fathoms also; the latter soundings are, however, oazy. On the western extreme of the Nymph Bank, are 59, 55, and 53 fathoms; and the south-western extremes of the said bank lie in 60

and 64 fathoms. Proceeding easterly, you will retain nearly the same depths until you advance as far as the longitude of 8° 26′, where you will find as little as 53 and even 45 fathoms—coarse, tenacious, light ground. The former depth, 45 fathoms, is the shoalest part of the Nymph, and is in latitude 50° 32′ N., and longitude 8° 26′ W.; to the south-westward of this, the soundings vary from 50 to 60 fathoms, and to the eastward of the latter depth, 69 fathoms, they shoalen pretty gradually toward the western coast of Cornwall, 9 leagues from which are 34 fathoms.

THE NYMPH BANK lies nearly midway between the English and Irish coasts, and shoals in irregular, uneven patches. It takes its rise in the vicinity of the Hook Lighthouse, and thence trends along the Irish coast round Cape Clear, even as far westward as the meridian of Dursey Island. It is very steep, particularly on its south-eastern and western edges, and the quality of the ground thereon is principally, though not wholly, that of coarse and fine sand; in some places, however, oaze will come up with the lead. Indeed, the deeper parts are wholly oaze, though not very tenacious.

S.W. OF THE SMALLS.—The soundings, on a radius of 16 leagues from the Smalls Lighthouse, in any direction between N.W. by W. ½ W. and S.W. ½ S., are nearly wholly oaze, or sand mixed therewith. To the north-westward, as well as to the eastward of these limits, the bottom suddenly becomes a sort of dark-reddish sand, which ground is the peculiar criterion of an approach to the Bristol Channel. In running from the westward for the mouth of the Bristol Channel, therefore, if the ground brought up by the lead be oaze, or sand mixed therewith, you cannot be to the southward of 50° 57′ N., but must be to the northward of that parallel, and to the westward of the meridian of Grasholm, let the depth be what it may. If, on the contrary, the soundings are wholly free from oaze, you must be to the eastward of the latter meridian. The transition from oaze to sand in the neighbourhood is so evident that it cannot be mistaken.

SOUNDINGS WESTWARD AND SOUTHWARD OF SCILLY.—Taking a supposed radius of 6 leagues from Scilly, in any direction from N.N.W. to S. ½ W., there is but little variation in the soundings, which consist chiefly of fine or coarse sandy mixed ground, of a pale white or greyish colour, with a mealy surface, and small stones and pieces of shells, and from 55 to 60 fathoms; it shoals gradually as you approach the rocks. The ground to the southward of the islands within the above radius, though in quality nearly the same, is somewhat finer and more tenacious than that to the westward and north-westward.

In a radius of 12 leagues from the same, and between the above-

named bearings, are 63 to 67 fathoms; and should oaze form any part of the soundings, your situation can neither be to the southward of 49° 38′, nor to the northward of 50° 17′, but upon or between those parallels; if the bottom be fine or coarse sand like beaten pepper, or light-grey sand, or reddish-brown with minute pieces of convex shells, or of *any* quality *without oaze*, in such case you must be *upon* or to the *northward* of 50° 17′, or *upon* or to the *southward* of 49° 38′, and in the fairway of the Channel.

Should the weather be thick, do not approach Scilly within the depth of 56 fathoms, as you will not then be more than 3 leagues from the rocks.

THE FAIRWAY OF THE CHANNEL, when eastward of Ushant or the Lizard, should always be considered as within the limits of 4 and 8 leagues from the English coast, if the wind will permit; not only in consequence of the dangers which exist on the opposite coast, but because the soundings increase and decrease more *progressively* on the English coast than on that of France, insomuch that, with reference to the above limits, the depths of water between the different meridians may be calculated upon with certainty in the undermentioned proportions, viz.:—

Between the meridian of the Lizard	and that of the Start . . .		2 fathoms every 5 leagues.
„ Start . . .	„	Lyme Regis .	3 fathoms every 4 leagues.
„ Lyme . . .	„	Portland . .	No variation.
„ Portland . .	„	Dunnose . .	Varying from 28 to 36 fths.

A close attention to the peculiar character of the soundings, together with the remarkable ripplings and overfalls which so universally prevail, even in the finest weather, off the French shore, will always demonstrate your position, as to whether you are northward or southward of the Channel Fairway.

When to the eastward of the Start, if the water deepens from 37 to 40 fathoms, to 50, 55, or 60, conclude yourself to be in the stream or parallel of the Casquets, and you should, therefore, haul to the northward in order to regain the Fairway as quickly as possible, to avoid the influence of the Gulf of Avranches and Channel Islands.

BEST LINE OF APPROACH.—Vessels bound into the Channel from the south-westward should run well to the northward, when eastward of the meridian of 10°, until oaze forms part of the soundings; and all vessels bound there from the north-westward should, for the same reason, borrow well to the southward, when eastward of that meridian, until the soundings are free from oaze; thus infallibly insuring a safe parallel, in the first instance, whereon to run eastward; and as during the prevalence of strong southerly and westerly winds, the tides are

warped more astream than usual, and found to run considerably longer, as well as with greater velocity, between the north and west, than at other periods, it is recommended (having in view the preservation of any particular parallel) that, when running from the edge of soundings towards the Channel during spring-tides, and with the wind blowing strong from between south and west, the course should be taken at S.E. by E. instead of, as usual, S.E. by E. ½ E.

USHANT.—This is an island four miles long and two broad, and is nearly in the same longitude as the Lizard; therefore, a ship being abreast of either of these places may be considered to have entered the British Channel. In the parallel of Ushant, and 16 leagues distant, you will have 70, 71, or 72 fathoms, the bottom a coarse pale-yellow, having a mealy substance with broken shells, and a substance like chaff. At 9 leagues distant, in the same parallel, there are from 63 to 66 fathoms; and even within *three* leagues, the same depth—therefore, in thick weather, come no nearer to Ushant than 70 fathoms.

The North-West Stream—or, as it is termed by many, "THE INDRAUGHT of the British Channel"—often runs at the rate of 1½ mile an hour or more; and in light winds and *thick* weather, when observations cannot be obtained, the utmost care is requisite in proceeding for the Channel, in order to satisfy yourself that this current has not thrown you into an unsafe parallel.

DIRECTIONS.—When running up Channel during the night, or in thick weather, do not approach Scilly within 60 fathoms, as you will not, in that depth, be more than 5 leagues from the islands: neither come into less water, when between Scilly and the Lizard, than 44 fathoms, by which precaution you will pass at least 2 miles to the southward of the stream of the Wolf, the parallel of which cannot be approached eastward or westward of the rock, so long as you preserve that depth. In the parallel of the Wolf there is 38 fathoms, and from 34 to 37 fathoms between it and the land. At 5 leagues W.S.W. of Scilly, the soundings will be 56 to 58 fathoms; and as you approach toward the Lizard from this position, it shoals to 44 fathoms at 4 leagues distant, and 51 fathoms at 8 leagues from it, and on its meridian. Sand and coarse gravel, with small stones, is the general character of the bottom between Scilly and the Lizard.

In proceeding to the eastward from the Lizard during the night, keep the lights in sight to the southward of the Beast. This precaution will lead at least 1½ mile to the southward of Black Head, and direct to the Eddystone. In thick weather come no nearer the Lizard than 47 fathoms, as a vessel will then be only 6 or 7 miles distant from it.

The course, from any position off the Lizard to a corresponding position off the Start, is about E. ¾ S., distance 21 leagues. Between these headlands, do not go into less water than 42 fathoms, by which precaution you will pass at least 5 miles to the southward of the Eddystone, the parallel of which cannot be approached eastward or westward of that rock so long as that depth is preserved. In the stream of the Eddystone there are from 34 to 37 fathoms; the ground in the former depth consists of coarse and of fine sand, but in the latter a sort of dark-greenish oazy sand, and extends nearly 10 miles in a westerly direction, and 4 miles in a southerly direction. Endeavour to round the Start Point within the distance of 5 or 6 leagues, or in 38 and 39 fathoms; by which means you will avoid the Channel Islands' indraught, even during the period when its effects are most to be apprehended—that is, between low water and 5 hours' flood.

From any position off the Start to a corresponding one off Portland, the course is E. ¼ S., distance 49 miles; and from any position off the Start to a corresponding position off St. Catherine's Point, the course is about E. by S., distance 93 miles. By altering the courses successively between the meridians of the different headlands, as a vessel advances up the Channel, she will better counteract the direct effects of the stream. When navigating between the Start and Portland, do not approach the shore within the depth of 30 fathoms until the meridian of Portland is passed; and when between Portland Bill and St. Catherine's Point, go not into less water than 25 fathoms. The former precaution will keep a vessel to the southward of the Shambles and the Race, as well as in the fair stream of the tide; and the latter will prevent her from experiencing the strong indraught caused by the flood running into Christchurch, the Needles, and Freshwater Bays, the duration of which is considerably prolonged by southerly and south-westerly winds. The depths of water, however, to the south-westward, southward, and south-eastward of the Casquets, within the supposed radius of 3 leagues, do not materially differ with those in similar directions from Portland; so that it is possible in bad weather, under a combination of disadvantageous circumstances, for the former to be mistaken by a stranger for those of the latter, particularly if hazy weather intervene, so as to prevent the revolving lights of the Casquets from being distinguished, unless, indeed, soundings were accidentally struck on a bank which lies S.S.W. from the Casquets. For it must be recollected that there are six different positions in which the *three* lighthouses on the Casquets will appear as *two* only, the first of which is only removed 2 points from the bearing of those on Portland—viz., N.W. ¾ W. or S.E. ¾ E., E. ¾ N. or W. ¾ S., N.E. ½ E. or S.W. ½ W.;

secondly, that the variation in the distance from the Lizard to Portland, and from the Casquets, does not exceed 7 or 8 miles; and lastly, that this is the norrowest part of the Channel westward of Beachy Head. Should a stranger, therefore, be placed in such a predicament during a winter's night, between the periods of low water and three-quarters flood, with a gale between N.W. and S.W., the consequences may easily be anticipated. This is a strong and unanswerable argument for a uniform and constant progressive attention to the lead from the instant of first striking soundings, by which such a disastrous situation can alone be successfully avoided.* The Casquets bear from the Start Point S.E. ¾ S., and from the Bill of Portland S. by W. ¾ W., 48 miles.

The course from any position off Portland to a corresponding position off St. Catherine's Point, is about E.S.E. ½ E., 45 miles; and from thence to Beachy Head, E. by S., 60 miles. In the latter interval, a vessel should not approach the shore within the depth of 25 fathoms; by which precaution she will pass without or to the southward of the Elbow of the Owers, and also preserve the fair Channel tide.

Between the Isle of Wight and Cherbourg, the soundings, with reference to the Channel Fairway, are so irregular, that the course for a running ship cannot be designated with that degree of precision which the narrow limits of the Channel require: at the same time these transitions from deep to shoal water will be equally in favour of a working ship, or of one crossing the Channel. The general quality of the bottom to the southward of the fairway is coarse, loose, unconnected, or rocky; the stones are in general covered with a reddish incrustation. Within 15 miles of the coast of Hampshire and Sussex, the soundings become finer, being chiefly sand mixed with fine gravel, which continues as far eastward as Beachy Head.

The ground between Beachy Head and Dungeness is, generally speaking, shoal as well as flat; nevertheless, the depths from the offing towards the shore decrease so regularly, that the land to the westward of Dungeness can be made with safety, in the thickest weather, by the lead.

The course from Dungeness to the South Foreland is E.N.E. ¼ E., and the distance 20½ miles, the depth of water varying from 17 to 13 fathoms. Whether turning to windward in thick weather, either up or down Channel, between Dungeness and the Foreland, do not stand in shore into less than 12 fathoms; which will keep her to the southward of the banks near Dungeness, and of the rocks off Folkestone.

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* *The Channel Pilot.* Part I. Printed for the Hydrographic Office, Admiralty, and sold by J. D. Potter, 31, Poultry, London.

Between half-flood and half-ebb, a vessel may stand freely off, bearing in mind, however, that there are not more than 17 feet at half-ebb on the Ridge; but after half-ebb, all vessels should endeavour to keep between the Varne and the English coast, by tacking near the Varne, when the South Foreland lighthouses bear N.E. ½ N. In standing in shore at night, between Hythe and Eastware Bay, go about when the Foreland lights are shut in by Shakspeare Cliff; off Folkestone, the helm should be put down when the high light disappears.*

THE BISHOP ROCK bears from St. Agnes W. ½ N., 4½ miles.

DANGERS NEAR THE LAND'S END.—The Runnel Stone, Wolf Rock, Longships, and Seven Stones.

THE WOLF ROCK lies E.S.E. ¾ E., 21 miles from Scilly Lighthouse, 23 miles W.N.W. from the Lizard Point, and is only 1¼ mile to the northward of a supposed straight line drawn from the former to the latter. The Longships light bears from it N.E. ¼ N., 7¾ miles.

The Wolf is very steep on all sides, and is awash at high water neap tides, though covered on spring floods. A light has to be built on this rock.

SEVEN STONES, a cluster of rocks, lying N.N.W. and S.S.E., about a mile in extent, with 38 to 40 fathoms at a mile distant, in all directions. In navigating this channel, the lightvessel should be kept westward of north, when going to the northward; and westward of south, when going in the contrary direction.

RUNNEL STONE—S.S.E., 4 miles from Longships; when the light is visible you are clear of the Runnel Stone Rock.

THE STAGS—off the Lizard; they extend to nearly half a mile from the coast, and have from 5 to 9 fathoms close-to and among them.

MANACLES ROCKS.—Some of the rocks are barely covered at high water. They lie S.S.W., 5½ miles from Pendinnis Point; S. by E., 3 miles from the entrance to Helford; and E.N.E., 3 miles from Black Head.

The eastern land of the Lizard (the Beast), open of Black Head W. by S., clears you of the rocks about a mile. At night the Lizard lights kept in sight, clears you 3 miles to the southward.

FALMOUTH.—The lighthouse is on St. Anthony's Point, at the east side of the entrance; some rocks extend a short distance off it.

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* In running up Channel, during thick weather, strangers are often at a loss to know whether they are to the eastward or westward of Dover; but there are certain distinctions in the cliffs which afford the pilots the necessary information in hazy or misty weather, and which it is desirable all seamen should know. To the westward of Dover, the cliffs present a smooth white surface, with small patches of dark grass; whilst to the eastward, they are marked with vertical strata of flint.

Old Wall, or Pinnacle Rock, of 26 feet, lies 1¼ mile from St. Anthony's Point; marks—Milor or Pennarrow Point, midway between St. Anthony's Point and the extremity of the rocks running out from it, bearing N. ½ W. When on it, St. Maw's Castle is hid by St. Anthony's Point.

Having passed the Lizard, bound to Falmouth, keep the Lizard lighthouses open of Black Head until St. Anthony's Light (flashing every 20 seconds) bears N.N.E., which clears the Manacles. If you are only going to the outer anchorage, steer up, with St. Anthony's bearing N.N.E., until within about 2 miles from it; then keep more to the N.W., and anchor, as convenient, in 8 or 10 fathoms, with the light about N.E. by E.: the harbour will then be open, in case the wind should get round to the eastward.

At the entrance at Falmouth, there is the Black Rock, which dries, with a beacon on it; it lies nearest the west shore: vessels may pass on either side of it, but the east side is the better passage. In proceeding to Carrick Road, keep in the fairway, and the lead going, as there is a narrow, deep channel all the way of 16 to 18 fathoms. You may borrow on St. Maw's side in 5 or 6 fathoms; or, steer up with Killaganoon House in line with Pennarrow or Milor Point, N. ½ E., which leads in the centre of the channel, between the black buoy on the east side, and the white buoy on the west side of the narrowest part of the channel. When past the buoys, you may anchor in Carrick Roads in 12 to 18 fathoms.

NOTE.—Vessels drawing not more than 18 feet, can use the channel westward of the Black Rock at all times of tide. Take the centre of the channel, and steer N.E. by N.

THE UDDER ROCK.—It lies 4¾ miles W. ¾ N. from the Loo Island, and is dry at low spring tides.

THE HAND DEEPS lie N.W. ½ N., 3¼ miles from the Eddystone, with 22 feet water on them; and the EAST RUTTS, E. by S., 11 miles; and from the Mewstone, S. by E. ¾ E., 7 miles.

PEAR-TREE ROCKS AND SUNKEN ROCKS OFF THE START.—The former of these are partly visible, and lie within three-quarters of a mile westward of the Start Point, and a less distance off the Pear-tree Head; the Sunken Rock is nearly a quarter of a mile east of the Start; to be safe, give the point half a mile berth.

THE SKERRIES OFF THE START.—The S.W. end is four-fifths of a mile E. ¼ S. from the lighthouse; it thence extends 3⅓ miles in a N.E. by E. ½ E. direction. Prawl Point, open of Start Point W. ½ N., leads southward of them. At night keep outside of 20 fathoms water.

TORBAY.—From Berry Head to Hope's Nose is N.N.E. ½ E., 3 miles. Berry Head is bold-to, but the Orestone should not be approached

nearer than 2 cables. The Nimble Rock, with 4 feet, lies S. 50° E. (true) from Froward Point, one-third of a mile. The Start light open on either side of East Blackstone, clears it.

The anchorage is in 6 to 8 fathoms, sand and clay; Brixton Church, on with the pier, about S.W., and Berry Head from S. to S.S.E., or further to the northward towards Torquay, in fine weather.

PORTLAND RACE AND SHAMBLES.—The west end of the Shambles is 2¼ miles from the pitch of Bill of Portland, S.E. ½ E.; its eastern end from ditto E.S.E., 4¼ miles: the shoalest part (11 feet) is near the centre.

Wyke Church (Regis) well open to the northward of the N.E. point of Portland N.N.W. ¼ W., leads to the eastward of the shoal in 12 fathoms; at night pass in 14 fathoms.

To go between the Race and Shambles, bring Portland lights in one, N.N.W. ½ W., until the N.E. point of Portland bears N.N.E. ½ E. to N.E.; then run along shore in from 9 to 14 fathoms.

NOTE.—During the N.E. stream of tide, it will be necessary that the highest or north-westernmost light should be kept open to the southward of the lowest or south-easternmost light to counteract its effects, as it sets directly for and with great velocity over the Shambles, and the south-western stream sets as strongly into the Race. This channel should never be attempted without a commanding breeze.

ANCHORAGE IN PORTLAND ROADS.—You may now anchor within the breakwater, in from 3 to 8 fathoms. Round the vessel (bears a red light at night), which is moored off the end of the works, and anchor where convenient, lying snugly sheltered from S.E. gales.

NEEDLES CHANNEL AND BUOYS.—The Needles Light is exhibited from the Tower on one of the Needles Rocks. The light is about 80 feet above high water.

Hurst Lighthouses are situated on the low point of Hurst Beach; the highest is 66 feet above the level of the sea. They are painted red, with a red beacon near them.

The Shingles Bank extends W.S.W. and E.N.E., about 3½ miles in length; and from its S.W. extremity, Hurst Castle bears E.N.E. about 3½ miles. This part is connected with the Isle of Wight by a *ledge* called the *Bridge*, on which the greatest depth at low water spring tides is 5 fathoms, one-third of a mile from the Needles Rocks there are only 3 fathoms. Three buoys are on the S.E. side of the Shingles.

The red S.W. Buoy of the Shingles, with bell, lies in 5 fathoms, a quarter of a mile westward of the tail of the shoal; its marks being the red beacon on Hurst Point in one with the High Lighthouse E.N.E., and the Needles Rock lighthouse S.E. by E. ¼ E.

Elbow Buoy (striped black and white), in 6 fathoms; marks—Hurst

High Lighthouse E.N.E., Needles Lighthouse nearly S.S.W. ½ W., and Sconce Point E. ¾ N.

N.E. Buoy (chequered red and white), in 5 fathoms; marks—Hurst High Lighthouse N.E. by E. ½ E., and Needles Lighthouse S.W. ½ W.

Warden Ledge Buoy (black), in 5 fathoms; marks—Sconce flagstaff, over the low part of Cliff's End, E.N.E. ¾ E.; and Lymington Church, touching the point of Hurst Beach, N.N.E. ¼ E. The Needles white light bearing S.W. by W. to S.W. by W. ½ W., clears the Warden Ledge.

NOTE.—A vessel cannot steer a direct course from the Elbow to the N.E. buoy, as she would shoal into 9 feet.

VESSELS BOUND TO THE NEEDLES CHANNEL.—Being off Portland about 4 miles, with the lighthouse N.N.E., a course E. ¼ S., distance 34 miles, in fine clear weather, guarding against the tide, will take you up to the S.W. buoy of the Shingles, passing Durlestone Head about 2 miles off. Avoid, in the day time, bringing Nodes' beacon to the northward of the Needles Point to clear the Shingles, until Hurst Lighthouses are in one, bearing N.E. by E. ½ E., then run over the Bridge with that mark. By night do not bring the Needles Rock light to the southward of E.S.E., or lose the white light until Hurst High Lights are in one, bearing N.E. by E. ½ E., then run over the Bridge with that mark, and when the Needles Light is S.S.W., keep Hurst High Light a little open to the eastward of the Low Light; steer up the channel with the latter mark, and take care not to lose sight of the white light in the Needles Lighthouse, for should you open the red light you will be near the Warden Ledge; from thence continue mid-channel between Hurst and Sconce Points.

In going out Hurst Lights should be kept open.

SAILING INTO SPITHEAD AND ST. HELEN'S BY NIGHT.—Keep St. Catherine's Light in sight until the Nab Light bears N.N.E.; then steer for the Nab Lights, passing a little to the eastward of the lights. If going to St. Helen's Roads, steer to the N.W.; anchor in 6 or 9 fathoms, with the Nab Lights S. by E., or S.S.E.

If bound to Spithead, bring the Nab Lights to bear south; steer up until the Warner revolving light (every minute) bears N.W. ½ N. to N.W. by N.; then steer for it, passing on the north side of it; then, by keeping the Nab Lights just open westward of the Warner Light, it will take you into Spithead.

WORKING INTO SPITHEAD.—Stand towards the Dean Tail and Elbow into 7 fathoms; to St. Helen's Road 8 or 7; to the Warner, 15 or 14; to the Elbow, 9 or 8; to the Horse, 15; and to No-man's Land, 17

fathoms. When standing towards the Warner and No-man's Land, tack the first shoal cast, it being steep-to, and the western tide sets over them.

THE OWERS.—The Owers lie off Selsea Bill. When to the westward of the lightvessel, do not bring it to bear eastward of S.E. by E.; if from the eastward, keep it to the northward of W. by N., and go into not less than 10 or 12 fathoms. Pass to the southward of the light.

ROYAL SOVEREIGN AND HORSE SHOALS, OFF BEACHY HEAD.—Seaford Cliff kept in sight to the southward of the pitch of Beachy Head, will lead at least 2 miles to the southward of the Southern Head. At night, vessels coming from the eastward will open Beachy Head Light to the southward of Beachy Head Cliffs, when it bears N.W. ¾ W.; and whether bound up or down Channel, when to the eastward of Beachy Head, and within 9 miles of it, by keeping the light open they will pass about a mile to the southward of all the Royal Sovereign Shoals.

STEPHENSON'S SHOAL.—The eastern end lies 3¼ miles W. ½ S. from Dungeness Lighthouse. To avoid this shoal, keep Shakspere's Cliff, near Dover, open to the southward of the lighthouse. There are 3 or 4 fathoms on Stephenson's Shoal, with 4 or 5 fathoms around it. The South Foreland and Dungeness Lights in one, lead three-quarters of a mile to the southward; or, the latter E. by N., northerly.

TO ANCHOR IN DUNGENESS WEST BAY, which shelters from all northerly and N.E. winds, bring the lighthouse to bear E. ¼ S., and Fairlight Mill open of the church of that name. You will have 6 fathoms, and a good berth for starting, in the event of a change of wind. Vessels of light draught of water can go much nearer to the beach; eastward of Stephenson's Shoal, and towards the lighthouse, it is steep-to—12 and 14 fathoms close to the shore.

DUNGENESS EAST BAY affords good shelter to vessels of all classes, in from 4 to 12 fathoms, upon pretty good holding ground, with the wind between N. by E. and S.W. The dangers in this bay are the Roar and Swallow Banks. On the latter, which lies N.E. ¾ E. from Dungeness 3 miles, there are from 2½ to 3½ fathoms; but on the Roar, which is very shallow between Dym Church and Lydd, there is as little as 9 feet. A black buoy is placed in 3 fathoms, called Newcombe, 1½ mile to the N.E. of Dungeness. To the N.E. of the Roar, the Bank continues until about Hythe, having on it from 3½ to 4½ fathoms, at 1¾ mile from the shore, all good anchoring ground. Vessels would have a good berth in 6, 7, or 8 fathoms water, with the wind to the northward of E. by N., abreast of the Castle at Sandgate, and Folkestone pier-clock open of Mill Point.

The Varne is a shoal running in a N.E. by E. and S.W. by W. direction, and is about 4½ miles in length, between the depths of 7 fathoms at each end; its breadth varying from a half to three-quarters of a mile. The shoalest part (9 feet), about a mile from its N.E. end, bears S.S.W. ¼ W., 9 miles from the South Foreland; and S.W. by W., 8½ miles from Dover Castle. A large red beacon buoy is moored in 13 fathoms, near the north-east end of this shoal, with Folkestone Church bearing N.W. ¾ N., and South Foreland high lighthouse N.N.E.; and its south-west end is pointed out by the lightvessel, which exhibits a quick revolving red-light, and lies in 16 fathoms water, with Dungeness lighthouse W. by N. ¼ N., and Folkestone Church, North.

The Ridge is about 9 miles in length, and 2 broad; its shoalest part (6 feet) is 3 miles from the S.W. end. From this, Dover Castle bears N.N.E., 16 miles; Dungeness Lighthouse, N.W. ¾ W., 13½ miles.

Anchorage in the Downs.—Upper Deal Mill on with Deal Castle W.S.W. ¾ W., and the South Foreland upper light on with the south side of Old-stairs Point S.W. ¼ W., in 7 or 8 fathoms; or with Upper Deal Mill to the northward of Deal Castle W.S.W., and the Upper Foreland Light to the northward of Old-stairs Point.

A Vessel, in the Downs, parting her cable, or obliged to slip during a southerly gale and run through the Gull stream, must do so by bringing the South Foreland high lighthouse in one with the middle of Old-stairs Bay, bearing S.W. ¼ W., and pass to the westward of the Gull Stream lightvessel; from thence she should steer to the N.E., with the lightvessel in one with the South Foreland lighthouse, or the lightvessel bearing S.W. ½ W.; and when the North Foreland lighthouse bears N.W., or the North Sand Head lightvessel S.E., she may haul out to the eastward and lie-to in 18, 19, or 20 fathoms, taking care, in running through the stream, to come no nearer the Brake than 7 fathoms, nor to the Goodwin than 11 fathoms. While at the back of the Goodwin, do not come under 30 or 28 fathoms, nor bring the Goodwin lightvessel to the eastward of north, until you bring the South Foreland lights in one, W. by N., when you may pass the South Sand Head lightvessel close-to on either side, and proceed to the anchorage in the Downs.

Working Out of the Downs.—Cast towards the shore, if convenient, to get the first of the ebb; stand towards Deal, in 7 fathoms; tack before the Hope Sand comes on with Cap Point, to avoid Deal Sand; stand towards the Goodwin to 12 fathoms, or till the South Sand Head lightvessel bears S.S.W. ¾ W., but not more westerly; towards Walmer, into 9 or 8 fathoms; and to the South Foreland 12 or 11.

INVOICES.

INVOICE.—An account of goods sent by merchants to their correspondents at home or abroad, in which the peculiar marks, the numbers, the value, and contents of such packages are set forth; as also charges, such as freight, insurance, &c.

MANIFEST.

MANIFEST.—A document, signed by the master, containing the name or names of the place or places where the goods on board have been laden, and the place or places for which they are respectively destined; the name and tonnage of the vessel; the name of the master, and the name of the place to which the vessel belongs; a particular account and description of all the packages on board, with the marks and numbers thereon; the goods contained in such packages, goods stowed loose, the names of the respective shippers and consignees, as far as such particulars are known to the master. The manifest must be made out, dated, and signed by the master, at the place or places where the goods, or any part of the goods, are taken on board.

BILLS OF LADING.

BILLS OF LADING.—An acknowledgment, signed usually by the master of a ship, but occasionally by some person acting on his behalf, certifying the receipt of goods on board the ship, and engaging, under certain exceptions, to deliver the said goods safely at the port to which the ship is bound, either to the shipper or to such other person as he may signify by a written assignment upon the bills of lading, on the payment of the stipulated freight.

The exceptions in a bill of lading are—the act of God, the Queen's enemies, fire, and all and every other accidents and dangers of the seas, rivers, and navigation of whatever kind or nature soever. Sometimes these exceptions are limited in particular trades; thus, in the trade to and from the West Indies, the following limitation is added: "save risk of boats, so far as ships are liable thereto;" but the exception does not make the owner or master liable for a loss in the boats to which they would not be liable in the ship to which the boats belong.

Although the goods are shipped in pursuance of a charter-party, yet the master must sign bills of lading—the former being the instrument and evidence of the *contract* for the shipping and conveyance; and the latter being the evidence of and title to the particular goods *shipped for conveyance* under that contract.

On delivery of the goods on board, the master or his mate signs a common receipt for them, which must be returned to the master, or cancelled, on the bills of lading being delivered. Bills of lading ought to be signed within 24 hours after the delivery of the goods on board, the master having satisfied himself as to the quantity shipped and the condition in which they are shipped. The bills of lading should always be read previous to signing, as objectionable clauses might be inserted.

Three stamped bills of lading are usually made out—one for the merchant or shipper; another (which is sent by post) for his agent or consignee; and a third is retained by the master for his own use and security, and for his guidance in delivering the goods.

When the quantity, quality, or condition of the goods, or the contents of the casks, bales, or packages, are unknown, or the goods are liable to deterioration, the master ought to qualify his obligations in the bills of lading, by writing under his signature, "Quantity and quality," or "Contents unknown," or "Not liable for deterioration."

When the ship is hired by a charter-party, the bills of lading are delivered by the master to the charterer; but when goods are sent by a general ship* (that is, one in which the goods of several unconnected parties are laden, to be conveyed to the ship's port of destination), each person sending goods on board receive bills of lading for the same.

Upon delivery the goods at the port of destination to the shippers' factors, or assigns, the giving up of the bills of lading sent to the factors or assigns is a sufficient discharge; but the master may insist on a receipt.

Bills of lading are transferable, either by blank or special endorsement, like ordinary bills of exchange; and the master is bound to deliver the goods to the holder producing the endorsed bill, who has acquired a legal right to it.

In case several parties claim the goods, or where there is a doubt as to who is entitled to delivery of them, the master should lodge the goods in the custody of a wharfinger or warehouseman, so as to preserve his lien for the freight; and he should do the same if no such bill of lading is produced to him during the lay days, or the demur-

* In bills of lading of a general ship to consignees in England from consignors abroad, in order to have a remedy for demurrage, take care to have inserted the clause—"Consignees paying freight and demurrage."

rage days, when they are fixed; and then he should apply for a judicial authority to sell as much of the cargo as will pay the freight and charges.

CHARTER-PARTY.

CHARTER-PARTY.—The name given to a contract in writing, between the owner or master of a ship and the freighter, by which the former lets the ship, or part of the ship, under certain specified conditions, for the conveyance of the goods of the freighter to some particular place or places. Generally, however, a charter-party is a contract for the use of the whole ship.

No precise form of words or set of stipulations is requisite in a charter-party. The forms of charter-party may, and indeed in many cases must, be varied to suit the views and intentions of the party concerned.

A charter-party specifies the nature of the voyage, and expresses the terms on which the cargo is carried. The usual stipulations on the part of the owners or masters are, that the ship shall be tight, staunch, and strong, and in every respect seaworthy; well and sufficiently found with all the tackling, apparel, furniture, and provisions requisite, and with the proper complement of crew for the voyage; that the ship shall be ready by a day appointed to receive the cargo, and wait a certain number of days to take it on board; that, after lading, she shall sail with the first fair wind and opportunity for the port of destination (the dangers of the sea excepted), and there deliver the goods to the merchant or his assigns in the same condition they were received on board; and further, that during the course of the voyage the ship shall be kept tight and staunch, and furnished with sufficient men and other necessaries, to the best of the owner's endeavours. On the other hand, the merchant usually covenants to load and unload the ship within a limited number of days after she shall be ready to receive the cargo, and after arrival at the destined port; and to pay the freight in the manner appointed. It is usual, also, for each of the parties to bind himself in penalties for non-performances of the covenants, articles, and agreements in the charter-party; it is signed by the contracting parties and a witness.

A charter-party is generally under seal; but sometimes a printed or written instrument is signed by the parties, called a *memorandum* of a

charter-party; and this, if a formal charter-party be not afterwards executed, is binding. But in whatever form the writing may be, it must bear a stamp, in terms of the Stamp Act.

A charter-party when the ship is let at the place of the owner's residence, is generally executed by them, or some of them (and frequently by the master also), and by the merchant or his agent. In a foreign port it must necessarily be executed by the master or the owner's authorised agent (if such there be), and the freighter or his agent.

A charter-party executed by the master in his name, when he is in a foreign port, in the usual course of the ship's employment, and therefore, under circumstances which do not afford evidence of fraud, or when it is executed by him at home, under circumstances which afford evidence of the expressed or implied assent of the owners, is binding upon the owner.

The freighter may load the ship either with his own goods or with the goods of another, or he may re-let the whole or part to others, provided there is no clause in the charter-party prohibiting him from so doing.

The charter-party usually expresses the burden of the vessel; and, in so doing, care should be taken to state it according to the actual number of tons burden, or to the number in the certificate of registry.

The usual covenant, that the ship shall be seaworthy, and in a condition to carry the goods, binds the owner to prepare and complete everything to commence and fulfil the voyage.

The vessel must be properly dunnaged, agreeably to the usages of the trade in which she is engaged, or according as the nature of the cargo may require; and in the stowage of the cargo, the various articles must be arranged and placed in the most approved method, so as to prevent damage.

In all maritime transactions, expedition is of the utmost consequence —for even by a short delay the object or season of a voyage may be lost; and therefore, if either party be not ready at the time appointed for the loading of the ship; the other may seek another ship or cargo, and bring an action to recover the damages he has sustained.

If the charter-party stipulates for a full and complete cargo, the master must take on board as much as he can, with safety and without injury to the ship; and the freighter is bound to furnish the same, either of his own goods or the goods of others.

The master must not take on board any contraband goods, or have in his possession any false or colourable papers, and so rendering the ship liable to seizure; but he must take and keep on board all the

papers and documents required for the protection of the ship and cargo in all the countries to which he is trading.

If the master receive goods at the quay or beach, or send his boat for them, his responsibility commences with the *receipt* of them. With goods intended to be sent coastwise, the responsibility of the wharfinger ceases upon the delivery of them to the mate of the vessel, *upon the wharf.* As soon as he receives the goods, the master must provide adequate means for their protection and security.

After the vessel has been fully loaded, cleared at the Custom-house, and all the requisite Customs and other documents on board, and all other charges paid, the master must, as soon as the weather permits, commence the voyage without delay; but not so as to sail into tempestuous weather, or during a gale.

During the time of war, it is a usual stipulation that vessels shall sail with convoy: under this obligation, the master must repair to the place of rendezvous in proper time, and be careful to procure all the instructions issued by the commander of the convoy; and if the master neglect to proceed with convoy, he will be answerable for all losses that may arise from the want of it.

Having commenced the voyage, the master must proceed to the port of destination without delay, and without stopping at any intermediate port, or deviating from the straight course of the voyage, unless in case of convoy, which the master must follow as far as possible. A *deviation* from the usual course may be justified for the purpose of repairs, or for avoiding an enemy or the perils of the sea, as well as by the sickness of the master or seamen, and the mutiny of the crew.

It is usually stipulated in charter-party and bills of lading that a certain number of days, called *lay days* shall be allowed for loading and discharging the cargo; and that the freighter may detain the vessel for a further specified time on payment of a daily sum for such over-time *(demurrage).* If the vessel be detained beyond the two designated periods, the freighter is liable to an action on the contract, although the delay may not be attributable to any fault or omission on his part.

The lay days are either running days, including every day—or working days, excluding Sundays and Custom-house holidays—or weather working days. The charter-party should specify whether they are working or running days.*

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* In London, "days" means "working days," and Sundays and holidays do not count until the ship is on demurrage. After that, all days count.

Notice should be given every day that the ship is on demurrage, and the amount of demurrage due claimed. On Saturday, the demurrage for the following Sunday should be claimed.

When no *lay days* are specified, the length of time for loading and unloading must be determined by the nature of the cargo, or by the usual and customary time allowed at the port.

If any clause of the charter-party is ambiguous, the interpretation should be liberal; or if the charter-party is silent in respect to any point, the usage of the trade in which the ship is employed must be adopted.

By an exception in the charter-party—not to be liable for an injury arising from the act of God, the Queen's enemies, fire, &c.—the owner or master is not responsible for any injury arising from the sea or the winds, unless it was in his power to prevent it, or it was occasioned by his imprudence or gross neglect.

FREIGHT.

FREIGHT.—The sum paid by the merchant or other person hiring a ship, or part of a ship, for the use of such ship or part, during a specified voyage or a specified time.

The rate of freight is usually fixed by the charter-party or bill of lading; but in the absence of any formal stipulations in reference to the subject, it would be determined by the custom or usage of the trade.

In the absence of an express stipulation to the contrary, freight is not due until the whole cargo is ready for delivery, or has been delivered to the consignee in accordance with the contract for its conveyance.

If a consignee receive goods in pursuance of the usual bill of lading, by which it is expressed that he is to pay the freight, he, by such receipt, makes himself liable for the freight. But a person acting as *agent* for the consignor, and who is known to the master to be acting in that character, does not make himself personally liable for the freight by receiving the goods, even if he should enter them in his own name at the Custom-house.

If a portion of a cargo be thrown overboard for the necessary preservation of the ship and the remainder of the goods, and the ship afterwards reach the place of destination, the value of this part is to be answered to the freighter by way of general average, and the value of the freight thereof allowed to the owner. So, if the master be compelled, by

necessity, to sell a part of the cargo for victuals or repairs, the owners must pay to the freighter the price which the goods would have fetched at the place of destination, and therefore are allowed to charge the merchant with the money that would have been due if they had been conveyed thither.*

If the cargo, or any part of it, is damaged during the voyage through the fault or negligence of the master or crew, the freighter is entitled to compensation, being the amount of depreciation in the value of the goods, less freight; if, however, the damage arises from circumstances over which the master has no control,—such as the peculiar nature of the goods (even if this is increased by confinement in the ship), or the perils of the sea, the act of God,—the merchant must bear the loss and pay the freight.

The time and manner of payment of freight are frequently regulated by express stipulations in a charter-party, and when that is done, the payment must be according to the agreement; but if there be no express stipulation contrary to, or inconsistent with, the right of lien, the goods may be retained until the freight is paid,† for the master is not bound to deliver them, or any part of them, without payment of the freight and other charges in respect thereof. But the master cannot detain the cargo on board the vessel, as the merchant would, in that case, have no opportunity of examining the condition of the goods. When the master is doubtful of payment, the practice in this country is to send the goods to a public wharf (if there is no stipulation that they are to be delivered at any particular wharf), ordering the wharfinger not to part with them until freight and other charges are paid.

When a ship, before the completion of her voyage, becomes disabled from proceeding upon it, the master has the option, within a reasonable time, either to repair her or hire another—tranship, and forward the goods in the other. Upon their delivery by such means, he will become entitled to the freight—since the contract is for the delivery of the goods, not for the arrival of the ship in which they were first laden. If the merchant prevents or discharges him from doing this, the owners will be entitled to the whole freight. If the master declines to tranship, and, without requiring him to do this, the merchant agrees to accept the goods at the intermediate port, freight will be due according to the proportion of the voyage performed.

* If chartered, but have signed bills of lading to a consignee, before you part with the cargo the consignee should produce the endorsed bill of lading. He should also undertake for payment of freight according to bills of lading, particularly if you have any doubt of your charterer's solvency.

† The master cannot hold the cargo for demurrage.

PROTESTS AND SURVEYS.

In case of damage having happened during the voyage, or being suspected to have happened, to ship or cargo, the master should, within twenty-four hours of his arrival in port, cause a Notary Public, or, in a foreign port, the British Consul, to note a protest "against wind and weather," as the term is, giving the particulars of the voyage; the storms or gales encountered, as entered in the log-book; protesting that any damage that may have happened was caused by winds, bad weather, &c.

The protest need not be extended until it has been ascertained what is the nature and amount of damage, if any. A protest is not valid unless extended within six months from the date of noting.

And when a certain number of lay days are fixed for delivery of the cargo, the master must await the time, or, if no lay days have been fixed, he must await the usual or customary time allowed at the port of discharge for that purpose; and if, on the expiry of that time, the cargo be not fully unladen, he ought then to protest against the merchant or consignee, so as the ship may thereafter lay on demurrage. Similar protests ought to be taken at the expiry of the demurrage days; and at all events, before sailing with an incomplete lading, it seems necessary that the master should protest against the shipper or his agent, so as to put these parties on their guard as to the time when, and the circumstances under which, he sailed.

When a vessel has arrived at the port of loading, and the merchants who have covenanted to furnish a lading there are unwilling or unable to furnish a cargo on the expiration of the lay days allowed by charter, the master must note a protest against the merchants for non-fulfilment of the charter-party—after which he is at liberty to seek a freight in another direction, and claim compensation for loss of time, as well as any loss arising from his being obliged to accept a less remunerative freight than stipulated for in the original charter-party. It is improper to wait the demurrage days unless required so to do by the merchant.

It may be necessary, while opening the hatches, before breaking bulk, to hold a survey, in order to ascertain whether they have been properly secured, as, should this not be the case, and damage through leakage have thus occurred to the cargo, it will have to be sustained by the shipowner—stress of weather having occurred notwithstanding.

When it has been ascertained that damage has occurred, surveyors should be called to give a written report or certificate, as to the particulars of the damage. And in the event of the damage being repaired,

the same surveyors should be called to inspect the vessel, and give a written report, or certificate, as to the repairs which have been executed. The survey report of a cargo must particularise the goods damaged, mentioning their marks, numbers, &c.; and, being signed, must be given to the master of the vessel.

In surveying a cargo, merchants acquainted with the nature of the cargo should be called as surveyors; if in a dock, apply to the surveying officer. In surveying a ship, two ship-masters, or, in their absence, any two qualified persons, should be called as surveyors. It is not necessary, in either case, to call Lloyd's agents.

In case of dispute on discharging, if the surveyor declare the dunnage insufficient, the ship is liable for the damage in the bottom, although the surveyor may not be able to cite any authority as to what would have been sufficient dunnage. The general rule is, that the dunnage must be sufficient according to the nature and quality of the cargo.

LLOYD'S AGENT.

It is a very prevalent notion that Lloyd's agents have a controlling power over all ships in difficulties; but this is a mistake. The master alone is the responsible agent for all concerned; and unless he abandons his charge, or his conduct is such as to cause the existing authorities to deprive him of the command (which can only be done with the consent of the consignee of the cargo), the authority of the master cannot be dispensed with.

BOTTOMRY—RESPONDENTIA.

The contract of Bottomry is a pledge of the ship as security for the repayment of money advanced to the master or owner, for the purpose of enabling him to carry on the voyage. If the ship be lost on the voyage, the lender loses the whole of his money; but if the ship and tackle reach the destined port, they become immediately liable, as well as the person of the borrower, for the money lent, and also the premium, or interest, stipulated to be paid upon the loan. No objection can be made on the ground of usury, though the stipulated premium exceeds the legal rate of interest, because the lender is liable to the casualities of the voyage, and may not receive his money again.

When money is advanced upon the lading, the borrower is said to take up money upon Respondentia. In this distinction as to the subject-matter of the security, consists the only difference between Bottomry and Respondentia, the rules of English maritime law being equally applicable to both.

A Bottomry or Respondentia Bond has no settled or precise form, but it is necessary that there be expressed the names of the lender and of the borrower; those of the ship and master; the sum lent, with the stipulated marine interest; the voyage proposed; with the commencement and termination of the risk which the lender runs.

In the place of owner's residence, the master is prohibited from borrowing on Bottomry or Respondentia unless with his consent.

A vessel may be hypothecated (pledged) by the master in a distant port abroad—as if a British vessel in a British colony or in a foreign port; or of a foreign vessel in this country—provided that the money to be raised is absolutely required for the repairs and equipment of the ship; that he is not able to obtain money upon the present credit of himself and the owners; and that he has no means of communicating with the owners in sufficient time to answer the purposes for which he makes the pledge.

Money to be borrowed on Bottomry should always be advertised for, and that offered at the lowest rate of interest accepted. This regulation is intended to prevent the master from making any interested arrangement with the lender, and to enable the claim to be made upon the underwriters.

Where several Bottomry Bonds have been given at different periods during the course of the voyage, the last in date is entitled to the priority of payment—on this presumption, that the last loan advanced was the means of preserving the ship, and that, without it, the previous lenders would have wholly lost their security.

Whenever the master may pledge the ship, he may add the security of the freight, and, if necessary, he may likewise pledge the cargo; all of which securities are, accordingly, sometimes included in a Bottomry Bond over the ship, cargo, and freight. Sometimes a Bottomry Bond, is given as a collateral security, to be enforced only in case of the draft on the shipowner being dishonoured; with the understanding that, if the draft be duly accepted, no Bottomry premiums shall be exacted, but merely the cost of insuring the disbursements for which the bond was granted. If, however, the advances have been originally made on the security of such bills drawn by the master on the owner, or otherwise on personal credit, a Bottomry Bond subsequently taken would be null. A bond procured from the master by compulsion is void.

QUESTIONS

To be answered by Commanders of Steam Vessels under Examination in the Practical Use of the Steam Engine.

Explain the nature and use of the principal Valves and Cocks connected with the Boilers and Engines, commencing with the Boilers.

BOILER VALVES AND COCKS.

Explain the nature and use of Safety Valves?

A.—They are conical valves communicating with the boiler and opening outwardly; they are so loaded that when the steam in the boiler exceeds its proper pressure it raises the valve and escapes.

Every boiler is tested to bear a certain amount of pressure per square inch of internal surface, but only a portion of this pressure is allowed in practice. To prevent explosions from the too great pressure in boilers, an apparatus is attached to the steam chest, which consists in principle of an escape tube, which is loaded with a weight heavy enough to confine steam and prevent its waste, but not heavy enough to allow a dangerous quantity of steam to accumulate in the boiler. This apparatus is therefore called a "Safety valve," and is by law inaccessible to the engine-driver; who, however, has control over another safety valve (there are frequently more than one) for the purpose of letting out surplus steam, &c.

The Reverse Valve.—The *Reverse* valve is a small loaded valve fitted in front of the upper part of the boiler, and opens inwardly to admit air into the boiler at any time, when by suddenly blowing off steam, or by the engine using the steam too freely, there might be danger of its collapsing by too much external pressure.

Communication or Stop Valves.—They are spindle valves which can be screwed tight down on its seat, or raised, as the case may be; one is fitted in the steam pipe close to each boiler, to cut off the steam from either one or more boilers, should it be necessary.

Feed Valves.—They regulate the flow of the water into the boiler, and are fitted to the feed pipes to prevent the return of the water after it has been pumped into the boilers by the feed pumps.

Kingston Valves.—They are conical valves fitted into conical holes in the ship's side at the end of the blow-off pipe, and have spindles attached, working perfectly tight through stuffing boxes, and cross handles on the inner extremities, by which the valves can be forced out to admit water or else allow it to pass out, but when screwed tight it will prevent water passing either one way or the other.

All openings in the bottom of a steam vessel, except for the waste water pipes, are fitted with Kingston valves, a contrivance by which in case the blowing-out cocks being set, the water is prevented running out of the boiler.

Blow-off Cocks.—They are for blowing the water in the boilers out

into the sea, and also the brine which collects in the bottom of boilers. They are fitted at the bottom of the boilers.

COMMUNICATION COCKS.—They are used to keep the water in the boilers at the same level, or for shutting off the feed from one or more of them.

THE WATER GAUGE COCKS.—For showing the height of water in the boilers, in case of accident to the glasses, or the cocks getting stopped.

GLASS WATER GAUGE is used for the same purpose as gauge cocks, and, from being placed near them, it may be at once seen what quantity of water is in the boiler. A glass tube is fixed in front of the boiler furnished with a cock at top and bottom; the lower cock at such a depth as always to communicate with the water, and the upper one communicating with the steam: when both cocks are opened together the water will rise in the tube to the exact height that it is in the boiler, and thus show what quantity is within.

STEAM GAUGE is used to show the pressure of the steam more accurately than can be done by safety valve. It consists of a curved tube partly filled with mercury; one branch is open to the steam in the boiler, and the other to the atmosphere; to the tube is attached a scale divided into pounds, and this indicates exactly the pressure of the steam within; for every pound of pressure the mercury rises an inch.

HAND-PUMP FOR BOILERS is used for filling and feeding the boilers when the engines are stopped, or before lighting the fires.

ENGINE VALVES AND COCKS.

THROTTLE VALVES are thin circular plates fitted in steam pipe, close to the cylinder, for shutting off and letting on the steam, and for regulating the quantity; it is moved by a small lever at the side of the steam pipe.

SLIDE VALVE.—To admit steam to give the necessary motion to piston by shutting off and admitting steam to the cylinder and condenser.

EXPANSION VALVES are placed between the throttle and slide valves, for cutting off steam from the cylinder at any required part of the stroke, leaving the rest to be worked by expansion in the cylinder.

ESCAPE VALVES.—Valves for the purpose of letting off any *water* or strong steam that may be in the cylinder.

BLOW-THROUGH VALVES.—These valves are for the purpose of expelling by the admission of steam (sometimes before the engine can be started) the fixed air from the condenser and air-pump, to create a perfect vacuum.

FOOT VALVE.—A flat plate of metal filling up the passage between the air-pump and condenser; it opens to admit water and air from the

condenser, but prevents their return on the down-stroke of the air-pump bucket.

Delivering Valve.—A valve at the top of the air-pump for the purpose of preventing the return of water from the hot well.

Air-pump Bucket Valve.—A round valve which opens upwards when pressed by water in the air-pump beneath it, but when such pressure is withdrawn, falls shut by its own weight, so that no water can return which has once passed through.

Injection Valves and Cocks. —Valves used for the purpose of regulating the flow or injection of water for condensing steam: the valves are fitted on the condenser; the cock on the ship's side.

Bilge Pump Valves and Cocks.—The valves are fitted to the bilge pumps for opening and closing as the plunger ascends or descends; the cocks are fitted to the different bulkheads, for pumping from each compartment.

Stop or Sluice Valves to Discharge Pipes.—They are valves fitted in the ship's sides, in order to prevent water getting into the engines when at rest.

Jacket Cocks.—Cocks fitted in the jacket of the cylinder, so as to allow the condensed steam to escape before starting.

The Sniffling Valve.—Valves fitted at the opposite side of the air-pump to the condenser, and connected with the latter by a pipe under the air-pump; it opens when pressed by steam entering the condenser by the blow-through valve.

When the blow-through valve is open, the steam from the casing (the throttle valve being at the same time open, and the injection cock shut) rushes in and fills the condenser, and by its elastic force drives out through the sniffling or tail-valve any gases and water which may have accumulated in the condenser.

BOILERS.

1. If the safety valves were set fast, how would you relieve the pressure on the boilers, if the steam was up and could not make its escape?

A.—Keep the engine working with all the feed on, draw the fires, and partially open the blow-off cocks.

2. How do you ascertain the saltness of the water in the boilers?

A.—By means of the hydrometer or thermometer; the former should not indicate more than 20° of saltness, or the latter more than 215° of heat, when the water is boiled; also, by means of the salinometer, the water should not contain more than 8 oz. of salt to the gallon. Hydrometers should sink as far in boiled salt water as in cold fresh water.*

* Common sea-water contains about 1-33rd of its volume of salt and earthy matter, and boils at 213°, and 2-33rds is the proportion that ought never to be exceeded, as incrustation commences shortly before that point, the boiling point of which is 216°·7.

3. How would you manage to change the water in the boilers, if the blow-off cocks were set fast?

A.—Run down the steam, draw the fires, unscrew the sludge-hole doors, and let the water run from the boiler into the ship's bottom. Clear the cocks, refill the boilers and proceed.

4. On examining the boilers, and they are found to be thin, what measures would you adopt to prevent accidents?

A.—Work with a reduced pressure of steam.

5. How would you keep the boiler free from salt and incrustation?

A.—By frequently blowing off.

6. Is it requisite to have a hand-pump fitted to the boilers; if so, for what purpose?

A.—Yes; to fill the boilers when the steam is not up; or in case of accident to the feed-pump.

7. Explain the use of the gauge-glasses and gauge-cocks, fitted on the boilers?

A.—To show the height of the water in the boiler; the former at sight, and the latter by opening them.

8. If the mercury was blown out of the steam gauge by the pressure of the steam in the boilers, what would you apprehend was the cause?

A.—Excess of pressure of steam; or it might be caused by the pitching of the vessel.

9. What would you do to relieve the pressure of the boilers?

A.—Open the furnace doors, partially close the dampers, and ease the safety valves.

10. How would you regulate the height or quantity of water in the boilers?

A.—By the feed cocks.

11. When the steam is up, how is the feed applied to the boilers?

A.—By the feed-pumps if the engine be in motion; or by the hand-pump or donkey engine, if the vessel be stopped.

12. When it is not up, what is necessary to be done before the fires are lighted?

A.—The first thing is to *run up** the boilers by opening the blow-out cocks, and complete filling them with the donkey engine.

13. When the engines are stopped, what precautions are necessary with regard to the water in the boiler?

A.—It is necessary to keep the water pumped up to the proper level.

14. What is meant by a boiler priming?

* Fill them with water.

A.—The water passing through the steam pipe into the cylinders.

15. How would you prevent it doing so?

A.—By reducing the pressure; and, if there is sufficient water, blowing some of it off and pumping in a little cold. The introduction of tallow into the boiler is deemed the best remedy in case of priming.*

16. If the water in a boiler is suffered to get too low, what may be the consequences?

A.—As long as the tubes are covered with water no danger is likely to occur; but if the water sinks so as to leave any of them uncovered, they would soon burst by becoming unduly heated.

17. What height should the water stand in a common boiler above the flues.

A.—From 6 to 12 inches.

18. What height should the water stand in a tubular boiler above the tubes?

A.—About 8 inches.

19. If any of the tubes were damaged by the fire, leaky, what would you do, supposing you could not shift them?

A.—Plug them up either with wood packing or patent cement.

20. How do you detect the pressure of steam in a boiler?

A.—By the steam gauge or safety valve.

21. If the water in a boiler is suffered to get too high, what might be the consequences?

A.—The water in the boiler will overflow and find its way into the cylinder by the steam pipe, and probably cause a break down.

22. How would you know when the water in the boiler requires changing?

A.—By trying its density by means of the thermometer and hydrometer; or testing it by the salinometer.

23. Explain the use of the thermometer and hydrometer.

A.—The thermometer indicates the degrees of heat, and the hydrometer shows the density or saltness of the water.

ENGINES.

24. Explain the use of the cylinders.

A.—Cylinders are for containing the steam that is applied to give motion to the pistons.

25. Explain the use of the air pump.

A.—To remove condensed water, air, &c., out of the condenser and thus create a vacuum in it.

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* The tallow to be applied either by means of a droam fixed upon the bonnet of the feed-flap, or by a syringe on the end of the boiler.

26. Explain the use of the condenser.

A.—It is for condensing the steam after leaving the cylinder.

27. Explain the use of the eduction pipe.

A.—The communication between the cylinder and the condenser.

28. Explain the use of the hot-water cistern.

A.—It is a reservoir whence to feed the boiler with the warm water received out of the condenser.

The air pump removes the condensed water, air, &c., which collects in the condenser, passing it onward through the delivery valves into the hot well, from which the supply of water is derived to replenish the boiler; the temperature of such condensed water, and other contrivances, being available to prevent the boiler being supplied with cold water, as such would involve an unnecessary loss of fuel.

29. Explain the use of the piston, and how fitted.

A.—The piston is a hollow iron plug fitting the interior of the cylinder with great nicety, and packed so as to be perfectly steam tight, but with sufficient freedom of motion to enable it to work up and down; to it is connected a piston rod working through a stuffing box and a hole in the cover.

30. Explain the use of the stuffing box and glands.

A.—The use of the stuffing box is for containing packing to keep the piston air tight while working through the cylinder cover; and the glands keep the packing in its place.

31. Explain the use of the parallel-motion rods.

A.—They are for keeping the piston rod parallel to the inside of the cylinder.

32. Explain the use of the eccentric, and how fitted.

A.—It is used for the purpose of giving motion to the slide valves, and is fitted with an eccentric wheel, loose on the shaft, with a stop at a certain point for going a-head or reversing; the rod has a gab and apparatus for throwing it out of gear.

33. Explain the use of the starting lever.

A.—For working the slide valves by hand, when necessary to start or reverse the engines before the eccentric is set into gear.

34. Explain the use of the barometer.

A.—It is to indicate the amount of vacuum in the condenser; hence it is called the *vacuum gauge*, and sometimes the condenser gauge.

35. Explain the use of the steam gauge.

A.—To indicate the pressure of steam in the boiler.

36. The vessel alongside the wharf, proceed to get the steam up.

A.—I would run up the water in the boilers, by opening the blow-out cocks, and complete filling them, if necessary, with the donkey engine; then light fires.

37. When the steam is up, how is it applied to the engines to set it in motion?

A.—By opening the communication and throttle valves, and placing the slide valves in the proper position.

38. What precaution is necessary before the engine is set in motion?

A.—It is necessary to blow the water out of the condenser by means of the blow-through valve.

39. How do you start the engine?

A.—By admitting the steam into the cylinders to force the pistons up and down, and consequently give rotation to the cranks and paddles or screw. On moving the slides to admit steam to the pistons, the injection cock should be opened to admit water into the condenser to create a vacuum, otherwise the engines will move sluggishly; the throttle valve ought only to be partially opened at first, and the supply of steam increased as the ship gathers way.

40. Is it necessary to move the engine by the hand a turn or two before starting?

A.—It is; in order to force out the condensed steam.

41. The engines being started, regulate the injection cocks, so as to keep them going at full or reduced speed.

A.—The injection cock is kept open until the waste water-pipe is cool to the touch; the temperature of the condenser ought to be about 100° in these latitudes, but greater in warmer climates.

42. What is the use of the injection?

A.—To condense the steam as it enters the condenser from the cylinder.

43. How is the vacuum maintained in a condensing engine?

A.—By means of the air-pump.

Suppose the bucket to be at the foot of the air-pump; when the engine begins to move it upwards by means of the pump-rod, if there be any water above the bucket-valve, it will be lifted along with the valve, and this water pressing against the discharge valve, will raise it, and entering the hot well flow through the discharge pipe into the sea. When the bucket rises, it will leave behind it a vacuum, causing the water and gases accumulated in the condenser to press open the foot-valve, and to enter at the foot of the air-pump till the balance of pressure is restored, when the foot-valve will close from its own weight. When the bucket again begins to descend from the top of the barrel, the upward pressure of the discharge valve will cease, and the valve will therefore fall by its own weight, and by that of the water and atmosphere above it; as the bucket descends it therefore leaves a void behind it, and the pressure of the bucket upon the water and gases below it will cause them to raise the valve and pass above the bucket till it reaches the foot of the air-pump, when the ascent will commence as before. By this means the air and water are drawn out of the condenser, and discharged at the top of the air-pump.

44. How do you know when there is too much injection?

A.—By the discharge valves of the air-pump lifting too soon; thereby causing a bad vacuum in the condenser.

45. How do you know when there is not enough injection?

A.—When the condenser gets hot.

46. If the injection was not shut off when the engines are stopped, what would happen?

A.—The engine would get choked with water.

To clear out the water open all waste cocks and slides, and blow steam through delivery pipes.

47. If the condenser reject the injection, what would you do?

A.—Allow the engine to rest or stand, and throw a few buckets of water on the condenser to cool it, the engines on starting will then take the injection.

48. Would it be advantageous if an injection-pipe was fitted so as to take injection from the bilge, if required?

A.—It would; in case of the ship springing a leak.

49. If water should get into the cylinder, what might be the consequences?

A.—The piston, cylinder, or cover might be broken.

50. In running free with a heavy sea, and a jump upon the engines, what precautions would you take to endeavour to prevent damage to the engines?

A.—Stand by the throttle valve and injection, to close them when the vessel takes a heavy roll.

51. If one engine was damaged, what would you do in order to proceed?

A.—Disconnect the disabled one and proceed with the other.

52. If the eccentric should break, could the engines still be worked?

A.—Only by hand.

53. If a bearing becomes heated what would you do?

A.—Slacken the bolts of the covers, slow or stop the engine, and cool the bearing with water; and if it is very hot then apply hot water in the first instance to cool it, and then cold. Oil, with sulphur intermingled, is then to be administered, and as the parts cool down the screws may be cautiously tightened, so as to take any jump off the engine from the bearing being too slack.

The bearings of direct acting screw engines require constant watching, as, if there be any disposition to heat manifested by them, they will probably heat with great rapidity from the high velocity at which the engines work. Every bearing of a direct-acting screw engine should have a cock of water laid on it, which may be immediately laid wide should heating occur; and it is advisable to work the engine constantly, partly with water and partly with oil applied to the bearings. The water and oil ar mixed by the friction into a species of soap, which both cools and lubricates, and less oil is used than if water were not employed. It is proper to turn off the water sometime before the engine is stopped, so as to prevent the rusting of the bearings.

54. How would you slow an engine?

A.—By partially closing the throttle valves and injection cock.

When required to stop slowly, the engineer diminishes the supply of steam by means of the throttle valve *(at the same time easing the safety valve)*, and the motion of the engine is thereby retarded: he then disconnects the eccentric rod, or, as it is termed, "*throws the engine out of gear*," and puts the slide valves at half stroke by hand, which causes both valve faces to cover their parts; and the steam being thus completely cut off from the cylinder, the engine soon stops.

55. How would you stop an engine?

A.—By throwing the eccentric out of gear, and shutting the slide-valves and injection cocks.

56. Wherein does a high-pressure differ from a low-pressure engine?

A.—A high-pressure engine has no condenser and air-pump, the steam being discharged from the cylinder. In a low-pressure engine the steam passes into the condenser.

57. How do you admit tallow into cylinders, when the engines are at work, for the purpose of lubricating the pistons?

A.—By opening the grease cock on the cylinder at the up stroke of the piston, and closing it on the down stroke; that is to say, by opening it on the vacuum side.

58. What is meant by working the engines expansively?

A.—Adjusting the valves so that the steam is shut off from the cylinder at any required part of the stroke of the piston, and leaving the rest to be done by expansion in the cylinder.

59. How would you disconnect the engines if there was no disconnecting gear fitted?

A.—By taking the bolts out of the connecting rod caps.

60. What is meant by throwing the engines out of gear?

A.—Disconnecting the eccentric from the slide valve lever.

61. Why have two feed-pumps fitted, say one to each engine?

A.—In case of an accident to either, so that if one be disconnected, the feed may be supplied by the other.

62. Is it requisite to have branch pipes fitted to feed the pumps; if so, for what purpose?

A.—They are requisite for regulating the supply of feed to each boiler, so as to keep the water up to the proper level in each when the vessel lays over, or in case of accident to either boiler.

ANSWERS.

NUMERATION, *Pages* 11—12.

1.	598	2.	1783	3.	6086	4.	89063	5.	603240
6.	20600	7.	90092	8.	204641	9.	800800	10.	3006004
11.	5030040	12.	7700006	13.	10010010	14.	70704032	15.	45387025
16.	349004065	17.	100010001	18.	842248484	19.	909009092	20.	222000040
21.	305040008	22.	700700700	23.	202202200	24.	900000900		

1. One hundred and twenty-three. 2. Four hundred and seven. 3. Seven hundred and eighty-three. 4. Two thousand seven hundred and sixty. 5. Five thousand and sixty. 6. Seven thousand and thirty-six. 7. Thirty-seven thousand six hundred and fifty-four. 8. Eighty-seven thousand and fifty-four. 9. Six hundred and ninety thousand and six. 10. Eight million forty-seven thousand three hundred and twenty-eight. 11. Eight million five hundred and forty thousand three hundred and twenty-six. 12. Five million two hundred and ten thousand and seven. 13. Six million thirty thousand four hundred and five. 14. Five hundred and sixty thousand and seventy-five. 15. Three million and six. 16. One million three hundred and ninety-seven thousand four hundred aud seventy-five. 17. Twenty million eighty-four thousand two hundred and sixteen. 18. One hundred and twenty-eight million seven hundred thousand and forty-five. 19. Fifty-five million seven hundred thousand and five. 20. Seventy-six million fourteen thousand and fifty-nine. 21. Six million six thousand six hundred and six. 22. Fifty-six million seven hundred thousand five hundred and five. 23. One hundred and twenty million fifteen thousand and fifteen. 24. Two hundred and two million two hundred and two thousand and two hundred. 25. Two hundred and seventy-five million eight thousand and five. 26. Twenty million eighty-four thousand two hundred and sixteen. 27. Seventy-nine million thirty thousand two hundred and eighty-four. 28. Four hundred and eight million seventy-six thousand and thirty-two. 29. Four hundred and one million four hundred thousand and fifty-six. 30. Nine hundred and eighty million five hundred thousand and sixty.

SIMPLE ADDITION, *Pages* 12—13.

1.	1274170	2.	1634607	3.	1659291	4.	2333431	5.	1536206
6.	1536206	7.	1648127	8.	2067687	9.	9145198	10.	7485613
11.	8519039	12.	7498158	13.	9560155	14.	5621433	15.	6524956
16.	8238335	17.	3329175	18.	3724599	19.	4483647	20.	3312670
21.	3312707	22.	3018498	23.	2797285	24.	3519772	25.	20566726566

SIMPLE SUBTRACTION, *Page* 13.

1.	621571	2.	539540	3.	000001	4.	000009
5.	676001	6.	554999	7.	480895	8.	580998
9.	681179	10.	508871	11.	376999	12.	173386
13.	107510	14.	222419	15.	157406	16.	58024
17.	8261243256	18.	1358235814	19.	2006289547	20.	763595488
21.	5909085424	22.	9957614250	23.	78098951912	24.	7501213600
25.	9108901099	26.	227936793034	27.	9088910980901	28.	35353259969I

SIMPLE MULTIPLICATION, *Pages* 13—14.

1.	685295792	2.	1962965961	3.	1506172792	4.	1899328910
5.	550942443156	6.	45652143474	7.	3886950304	8.	5159176101
9.	9876543210	10.	9803614194	11.	7774239492	12.	11019283848
13.	1350705843	14.	2684444024	15.	5629618680	16.	8918232255
17.	13503780000	18.	55275801000	19.	39205962324	20.	61284228934
21.	15993780666	22.	49036019193	23.	27349835014665	24.	2258105550000
25.	770930181732	26.	47786304367	27.	263961479972	28.	5750745672129
29.	531954730112	30.	6295813800	31.	2997332184	32.	2466490572
33.	10285980	34.	16261578	35.	12838608	36.	40261296
37.	38114062	38.	24335360	39.	47094144	40.	20146968
		41.	28894158	42.	78522048		

SIMPLE DIVISION, *Page* 14.

1.	67896347-1	2.	194899128-2	3.	99836471	4.	49648952
5.	66779765-3	6.	39512348-1	7.	868427625-6	8.	274473675
9.	25409610-6	10.	100107478-9	11.	99557924-6	12.	4953087934-4

13.	463519673763533-5	14.	27201490438560034-10
15.	1582874324701-32	16.	187157296759729-46
17.	95022741046776-8	18.	14964459409277-63
19.	133683783399807-6	20.	4031632208110056-69
21.	27206980239559-123	22.	34045491087172-1
23.	329218107-670	24.	6897234900
25.	8607936214-143	26.	74063098764-33203
27.	24199350-230626	28.	48435530

LOGARITHMS OF NATURAL NUMBERS, *Page* 28.

1.	0·954243	2.	0·698970	3.	9·000000	4.	1·892095	5.	1·954243
6.	0·690196	7.	1·000000	8.	1·579784	9.	2·579784	10.	2·000000
11.	8·462398	12.	2·962369	13.	2·845098	14.	1·802774	15.	3·805501
16.	3·903307	17.	1·415974	18.	0·415974	19.	9·165244	20.	0·588160
21.	3·829561	22.	8·942504	23.	9·539954	24.	8.110590	25.	9·838597
26.	9·964240	27.	8·542825	28.	8·953760	29.	3·823213	30.	4·000000
31.	4·003891	32.	4·900406	33.	4·681241	34.	1·861194	35.	1·188590
36.	3·958124	37.	8·999957	38.	6·763428	39.	8·554755	40.	8·757654
41.	1·972043	42.	6·929419	43.	4·722552	44.	4·698970	45.	5·845154
46.	5·421604	47.	5·606388	48.	5·699759	49.	5·738463	50.	4·477134
51.	4·000039	52.	5·774152	53.	5·954242	54.	7·947385	55.	7·993714
56.	2·458852	57.	7·551938	58.	8·749845	59.	6·932847	60.	7·755341

NATURAL NUMBERS OF LOGARITHMS, *Page* 28.

1.	204	2.	4753	3.	238	4.	9	5.	50
6.	1	7.	700	8.	100	9.	88	10.	114
11.	366·855	12.	3659	13.	36·72+	14.	418·5+	15.	6122·69
16.	3·673	17.	6·004	18.	588·172	19.	594500	20.	264000
21.	1000	22.	2480000	23.	26·04+	24.	437·5	25.	15·43+
26.	1049·27	27.	·09	28.	·0091	29.	50800	30.	26·04+
31.	2·606	32.	·1	33.	·009	34.	·052	35.	10000
36.	1·7	37.	451069	38.	2·718+	39.	404007	40.	·02494
41.	100000	42.	·0762	43.	·147	44.	·00000075	45.	1·00043
46.	8859000	47.	·09185	48.	·03670	49.	5·806+	50.	·7639
51.	4220	52.	53·13	53.	·0424	54.	·004855	55.	2·515+
56.	36·92+	57.	8·465+	58.	100591	59.	·0002096	60.	7·50

MULTIPLICATION BY LOGARITHMS, *Pages* 30—31.

1. 5950; 1000; 1053; 3626; 7663.
2. 6391; 1203·6; 123·84; 412·56; 951·7.
3. 66·12; 10818; 3125·0; 984; 1111.
4. 6912; 340703; 810090; 69120; 611100.
5. 38608; 47600; 19012; 204; 1827000.
6. 9362·4; 985·68; 45675; 781·4; 2788·85.
7. 3192; 1259·64; 324·632; 862·14; 100000
8. 397476; 55·68; 508·8; 33360; 9025.
9. 111168; 437·5; 4900; 10246; 257·88.
10. 898·45; 39·44; 731·2; 584·69; 1688·2.
11. 72864; 3860·8; 1579·5; 2196·4; 23650·2
12. 951·7; 247·90; 4·189; ·47614.
13. 62·9154; ·018237; ·363054132.
14. ·01; ·00001; ·00010; 100000.
15. ·00005694; 610·7292; ·00297419; ·24790.
16. 2355·9; 4·189; 100000; ·0000000924.
17. 17·8176; ·0000001756; 229008.
18. 566·125; 42854; 23168.
19. ·0009072; 92·16; 21427.
20. 42854·4; 448109; 1·93181.

DIVISION BY LOGARITHMS, *Page* 33.

1. 83; 601; 84; 125.
2. 60; 500; 96·14; 59·60.
3. 45; 19; 7·2; 66·46+.
4. 304; 334·9; 396·0; 23.
5. 47·75; 36·45+; 28·96+; 1·44.
6. 10; 1; 238·1+; 100.
7. 184; 240·299+; 8844·03; 627·988.
8. 14·66: ·01466; 1·5; 1·915.
9. 0·26389; 26·389; 2·6389; ·0003789.
10. 0·00011405; 344·663; 14·66; 100·82.
11. 2187·23; 1011; ·148610; 1068·75.
12. 25·2457; 4725; 377; ·3440.
13. 1; 10; 99700 9; 1000.
14. 55·16; 14400; 1357·71; 1000.
15. 1195·16; ·0000002286.
16. 31131·8; ·00257246.
17. 25·26; 1295 71.
18. 3288·04 nearly.
19. They ought to be identical, or within a unit in the last place.
20. ·0511172; 2728·54.
21. ·0641774; 1971·39.

LOG. SINES, TANGENTS, SECANTS, ETC., *Page* 40.

NO.	SINE.	TANGENT.	SECANT.	COSINE.	COTANGENT.	COSECANT.
1.	9·079607	9·082763	10·003156	9·996844	10·917237	10·920393
2.	9·325098	9·663928	10·009974	9·990026	10·336072	10·674902
3.	9·611999	9·651805	10·039806	9·960194	10·348195	10·388001
4.	9·787595	9·890004	10·102409	9·897591	10·109996	10·212405
5.	9·497409	9·520002	10·002593	9·997407	10·479998	10·502591
6.	9·732252	9·807055	10·074803	9·925197	10·192945	10·267748
7.	9·832497	9·967258	10·134760	9·865240	10·032742	10·032742
8.	9·875079	10·054613	10·179534	9·820466	9·945387	10·124921
9.	9·923122	10·185903	10·262781	9·737219	9·814097	10·076878
10.	9·958771	10·339836	10·380065	9·619935	9·660164	10·041229
11.	9·246845	9·253720	10·006876	9·993124	10·746280	10·753155
12.	9·516536	9·541332	10·024796	9·975204	10·458668	10·483464
13.	9·784453	9·884989	10·100537	9·899463	10·115011	10·215547
14.	9·672452	9·726755	10·054304	9·945696	10·273245	10·327548
15.	9·860764	10·023176	10·162412	9·837588	9·976824	10·139236
16.	9·975130	10·457990	10·482859	9·517141	9·542010	10·024870
17.	9·993840	10·770507	10·776667	9·223333	9·229493	10·006160
18.						
19.	9·999579	11·356298	11·356719	8·643281	8·643702	10·000421
20.	9·986672	9·599289	10·612618	9·387382	9·400711	10·013328
21.	9·955206	10·319983	10·364777	9·635223	9·680017	10·044794
22.	9·938922	10·244180	10·305259	9·694741	9·755820	10·061078
23.	8·831988	8·832992	10·001004	9·998996	11·167008	11·168012
24.	9·864870	10·031944	10·167074	9·832926	9·968056	10·135130
25.	9·966727	10·390483	10·423756	9·576244	9·609517	10·033273
26.						
27.	9·977216	10·478075	10·500885	9·499141	9·521925	9·521925
28.	9·447622	9·465390	10·017768	9·982232	10·534610	10·552378
29.	9·815955	9·937432	10·121477	9·878523	10·062568	10·184045
30.	9·913869	10·156311	10·242442	9·757558	9·843689	10·086131

ARCS OF LOG. SINES, *Page* 41.

1. 33° 26′ 48″	2. 19° 15′ 35″	3. 29° 34′ 59″	4. 2° 55′ 26″	5. 2° 17′ 7″
6. 57 30 53	7. 53 12 30	8. 51 6 29	9. 58 15 30	10. 18 26 6
11. 39 7 15	12. 30 33 18	13. 21 15 0	14. 15 19 44	15. 31 57 10
	16. 30 4 43	17. 1 39 39	18. 4 1 28	

ARCS OF LOG. COSINES, *Page* 41.

1. 52° 13′ 35″	2. 55° 45′ 8″	3. 8° 6′ 31″	4. 81° 18′ 0″	5. 70° 47′ 25″
6. 80 37 20	7. 31 9 33	8. 3 56 42	9. 84 40 38	10. 84 15 39

ARCS OF LOG. SECANTS, *Page* 41.

1. 14° 23′ 15″	2. 51° 28′ 50″	3. 3° 24′ 0″	4. 26° 33′ 0″	5. 79° 39′ 51″
6. 39 22 9	7. 18 22 13	8. 28 3 33	9. 61 4 15	10. 71 27 48

ARCS OF LOG. COSECANTS, *Page* 41.

1. 26° 43′ 0″	2. 34° 1′ 14″	3. 22° 29′ 21″	4. 6° 5′ 16″	5. 49° 11′ 9″
6. 42 42 30	7. 5 43 39	8. 1 57 4	9. 1 6 53	10. 58 15 30
11. 7 13 56	12. 78 22 32	13. 13 33 27	14. 60 13 52	15. 50 57 26

ARCS OF LOG. TANGENTS, *Page* 42.

1. 77° 0′ 23″	2. 45° 0′ 24″	3. 81° 31′ 58″	4. 73° 46′ 29″	5. 54° 43′ 26″
6. 48 58 25	7. 86 58 16	8. 22 9 25	9. 57 36 3	10. 1 8 7
11. 23 43 17	12. 81 53 25	13. 35 3 31	14. 48 58 24	15. 15 40 53

ARCS OF LOG. COTANGENTS, *Page* 42.

1. 61° 3′ 33″	2. 7° 34′ 15″	3. 54° 56′ 28″	4. 41° 1′ 35″	5. 11° 0′ 41″
6. 15 54 34	7. 88 46 54	8. 58 15 30	9. 44 20 2	10. 44 58 55
11. 82 49 23	12. 8 30 34	13. 88 20 53	14. 76 40 15	15. 76 52 23

DIFFERENCE OF LATITUDE, *Page* 51.

1. 3° 23′ = 203′ N.	2. 7° 50′ = 470′ S.	3. 39° 24′ = 2364′ N.
4. 4 53 = 293′ S.	5. 10 0 = 600′ S.	6. 5 30 = 330′ N.
7. 13 15 = 795′ N.	8. 2 37 = 157′ S.	9. 10 10 = 610′ S.
10. 20 30 = 1230′ N.	11. 1 34 = 94′ N.	12. 13 51 = 831′ S.
13. 7 39 = 459′ N.	14. 8 2 = 482′ S.	15. 4 48 = 288′ N.

MERIDIONAL DIFFERENCE OF LATITUDE, *Page* 52.

1. 97	2. 1042	3. 2426	4. 345	5. 93	6. 735
7. 1381	8. 1216	9. 512	10. 607	11. 932	12. 260

LATITUDE IN, *Page* 53.

1.	34° 2′ N.	2.	27° 54′ N.	3.	0° 8′ N.	4.	47° 22′ S.
5.	3 1 N.	6.	46 21 N.	7.	2 48 S.	8.	36 51 S.
9.	2 54 S.	10.	0 20 S.	11.	Equator.	12.	0 15 N.
13.	Equator.	14.	39 14 S.	15.	Equator.	16.	1 14 N.

MIDDLE LATITUDE, *Page* 54.

1.	17° 19′	2.	26° 44′	3.	1° 20½′	4.	35° 37′	5.	51° 46′
6.	61 31½	7.	53 12½	8.	30 55½	9.	64 31	10.	6 52

DIFFERENCE OF LONGITUDE, *Page* 56.

1.	5° 0′ = 300′ E.	2.	2° 3′ = 123′ E.	3.	8° 27′ = 507′ E.
4.	11 56 = 716 W.	5.	4 20 = 260 W.	6.	4 30 = 270 E.
7.	6 15 = 375 E.	8.	6 30 = 390 E.	9.	7 2 = 422 W.
10.	6 8 = 368 E.	11.	7 0 = 420 W.	12.	3 0 = 180 W.
13.	61 38 = 3698 E.	14.	6 52 = 412 E.	15.	6 30 = 390 E.
16.	47 15 = 2835 E.	17.	24 12 = 1452 W.	18.	18 50 = 1130 W.
19.	126 27 = 7587 W.	20.	20 0 = 1200 W.		

LONGITUDE IN, *Page* 57.

1.	7° 38′ W.	2.	1° 18′ E.	3.	31° 4′ E.	4.	0° 30′ W.
5.	1 15 E.	6.	0 0	7.	1 40 W.	8.	0 45 W.
9.	0 23 E.	10.	39 10 W.	11.	29 10 W.	12.	99 6 E.
13.	103 56 E.	14.	178 26 W.	15.	178 57 E.	16.	180 0 E.
		17.	177 39 W.	18.	179 59 E.		

LEEWAY—TRUE COURSES, *Page* 58.

1.	S.W. ½ S.	2.	S.S.W. ¼ W.	3.	N. ¼ E.	4.	N.E. ½ E.
5.	W.N.W.	6.	S.E. ¼ E.	7.	E. ½ N.	8.	W. by N. ½ N.
9.	N. by W. ¼ W.	10.	S. ¾ W.	11.	E. by S.	12.	W. ¾ S.
13.	N.W. by W.	14.	W. ¼ S.	15.	S. ½ E.	16.	N. by W. ¾ W.
17.	N.E. by E. ¾ E.	18.	E. by S. ¼ S.	19.	W. ¾ S.	20.	N. by E. ¼ E.

VARIATION—TRUE COURSES, *Page* 64.

1.	N.E.	2.	S.S.E.	3.	W.S.W.
4.	N.W.	5.	N.N.E.	6.	S.E.
7.	S.S.W.	8.	N.W. by W.	9.	S.E. by E. ½ E.
10.	N.E. by E.	11.	N. ¼ W.	12.	N.E. by E.
13.	N. ¼ W.	14.	S.S.E.	15.	N.W. by W. ½ W.
16.	S.W. ½ W.	17.	S. ½ E.	18.	E. by S. ½ S.
19.	E.N.E.	20.	S. by E. ½ E.	21.	N.
22.	S.W. ¼ S.	23.	N.W. by W. ½ W.	24.	W. by S. ½ S.
25.	N. by W. ½ W.	26.	N. by E. ¾ E.	27.	S. by W. ¾ W.
28.	N. 77° E.	29.	N. 46½° W.	30.	N. 21° W.
31.	S. 66° W.	32.	N. 66° E.	33.	N. 24° W.
34.	S. 24° W.	35.	S. 78° E.	36.	N. 12° E.

LEEWAY AND VARIATION—TRUE COURSES, *Page* 67.

1. N.E.	2. S.S.W. ¾ W.	3. W. ¾ N.
4. N.E. by E. ¾ E.	5. N.E. ¼ E.	6. E. by N. ½ N.
7. S.W. ¼ S.	8. S.W. by S.	9. E. ¾ S.
10. S. ¾ W.	11. S.W. by W.	12. W. by S. ½ S.
13. S. by W. ¾ W.	14. S. ¼ E.	15. S.E. ½ S.
16. E. ½ N.	17. S.W. ½ S.	18. N.W. by W. ½ W.
19. S.E. by E. ¼ E.	20. N. by E. ½ E.	21. N.W. ¼ N.
22. S. by E. ½ E.	23. E.S.E.	24. S. by W. ½ W.
25. N.W. by W. ¼ W.	26. W. ½ S.	27. S.S.W. ¼ W.
28. N. ¾ W.	29. W. by N.	30. S.W. by S.
31. S. 89° W.	32. S. 1° E.	33. S. 32° E.
34. S. 74° E.	35. S. 59° W.	36. N. 15° E.

DEVIATION—TRUE COURSES, *Page* 74.

1. N. 38° 59′ E.	2. N. 0° 22′ W.	3. N. 20° 58′ W.	4. S. 43° 39′ W.
5. S. 84 8 W.	6. S. 24 5 W.	7. N. 32 24 E.	8. S. 48 55 E.
9. N. 19 25 E.	10. S. 0 16 W.	11. S. 81 19 W.	12. S. 36 12 E.
13. S. 87 29 E.	14. N. 42 2 W.	15. S. 28 57 W.	16. S. 4 38 E.
17. S. 73 10 W.	18. N. 32 24 E.	19. N. 2 59 E.	20. N. 89 45 W.
21. S. 9 33 E.	22. S. 78 10 W.	23. S. 63 11 W.	24. S. 4 50 W.
25. S. 66 0 W.	26. S. 74 3 E.	27. S. 79 16 E.	28. N. 74 57 W.

TRAVERSE SAILING, *Pages* 83—84.

NO.	D. LAT.	DEP.	LAT. IN.	COURSE.	DISTANCE.
1.	95·2 S.	92·1 W.	51° 23′ N.	S. 44° W.	132′
2.	20·0 S.	128·8 W.	53 52 N.	S. 81 W.	130
3.	375·8 S.	0·0	2 26 S.	S.	375·8
4.	0·0	76·8 E.	19 0 S.	E.	76·8
5.	75·2 S.	70·3 E.	0 15 S.	S. 43 E.	103
6.	120·1 N.	129·0 E.	0 50 N.	N. 47 E.	176
7.	99·0 N.	58·2 E.	0 37 N.	N. 30 E.	115
8.	30·5 S.	183·7 W.	49 27·5 N.	S. 81 W.	186
9.	35·7 S.	0·6 E.	46 36 N.	S. 1 E.	36
10.	85·0 S.	26·4 E.	53 36 N.	S. 17 E.	89
11.	1·0 N.	63·3 E.	38 41 N.	N. 89 E.	63
12.	17·8 S.	7·1 W.	56 41 N.	S. 22 W.	19
13.	145·8 S.	61·8 W.	2 26 S.	S. 23 W.	158
14.	9·2 N.	8·5 E.	34 9 S.	N. 41 E.	13
15.	35·2 S.	48·1 W.	1 24 S.	S. 54 W.	60
16.	50·6 S.	48·2 E.	0 19 N.	S. 44 E.	70

PARALLEL SAILING, *Page* 85.

1. 250·4′ W.	2. 344·4′ E.	3. 519·2′ W.	4. 294·8′ W.
5. 148·0 W.	6. 512·5 E.	7. 612·0 W.	8. 113·8 E.
9. 117·7 W.	10. 408·0 E.	11. 372·1 E.	12. 594·5 E.

MIDDLE LATITUDE SAILING, *Page* 88.

1.	D. lat. 113′·5	Dep. 273′·5	Lat. in 27° 38′ N.	D. long. 305′	Long. in 54° 55′ W.
2.	„ 99·9	„ 187·0	„ 34 10 N.	„ 223	„ 29 7 W.
3.	„ 89·8	„ 189·8	„ 41 0 S.	„ 248	„ 70 12 E.
4.	„ 165·6	„ 223·3	„ 49 10 S.	„ 334	„ 175 58 W.
5.	„ 96·7	„ 318·7	„ 18 53 N.	„ 339	„ 175 11 E.
6.	„ 122·9	„ 122·9	„ 0 59 S.	„ 123	„ 27 47 W.

MERCATOR'S SAILING, *Page* 92.

NO.	D. LAT.	M. D. LAT.	D. LONG.	COURSE.	DIST.
1.	97 N.	125	131 E.	N. 46° 20′ 33″ E.	140·5′
2.	85 S.	130	76 E.	S. 30 18 40 E.	98·46
3.	280 N.	497	368 E.	N. 36 31 4 E.	348·4
4.	81 N.	128	227 W.	N. 60 34 56 W.	164·9
5.	230 S.	500	270 E.	S. 28 22 9 E.	261·4
6.	430 N.	588	310 E.	N. 27 47 55 W.	486·1
7.	687 S.	785	3698 E.	S. 78 0 55 E.	3308
8.	1232 N.	1760	4732 E.	N. 69 35 53 E.	3534
9.	115 N.	166	191 E.	N. 49 0 21 E.	175·3
10.	1107 N.	1230	1452 W.	N. 49 43 55 W.	1713
11.	779 S.	1080	1200 W.	S. 48 0 46 W.	1164
12.	1011 N.	1139	3808 W.	N. 73 20 52 W.	3528
13.	792 S.	794	1254 E.	S. 57 39 33 E.	1480·5
14.	128 N.	233	725 W.	N. 72 11 1 W.	418·4
15.	315 S.	524	365 E.	S. 34 51 35 E.	383·9
16.	731 S.	733	2459 E.	S. 73 24 4 W.	2559
17.	150 N.	274	354 E.	N. 52 15 35 E.	245
18.	677 S.	950	1015 E.	S. 46 53 41 E.	990·7
19.	4483 N.	4842	3313 E.	N. 34 22 51 E.	5432
20.	1860 S.	1884	412 E.	S. 12 20 8 E.	1904
21.	3355 N.	3516	7587 W.	N. 65 8 9 W.	7979
22.	180 N.	190	1140 W.	N. 80 32 16 W.	1095

DAYS' WORKS, *Pages* 107—112.

1. True Courses.—S. ¾ W., 12′ dep. course; S. 6¾ W., 25′; S. 4¼ W., 22′; N. 7¼ W., 19′; S. ½ W., 16′; S. 1 W., 13′; S. 4½ E., 13′; N. 7 W., 6′ current course. D. lat. 65·7 S., dep. 61·2 W.; course S. 43° W., dist. 90′. Lat. in 48° 52′ N., diff. long. 94′. Long. in 6° 46′ W.

2. True Courses.—S. 5¾ W., 18′ dep. course; N. 1¼ W., 12′; S. 2¾ E., 18′: S. 3¼ E., 14′; N. 1½ W., 18′; N. 2 W., 17′; N. 1¼ W., 17′; N. 2¾ E., 18′ current course. D. lat. 42° 1′ N., dep 8·1 W.; course N. 11° W., dist. 43′. Lat. in 54° 58′ S., diff. long. 14′. Long in 180° 12′ W., or 179° 48′ E.

3. True Courses.—S. 7¼ E., 17′ dep. course; N. 5 E., 16·2; S. 7¾ E., 18·3; N. 5 E., 13·6; S. ¾ W., 14·8; S. ¼ W., 7·2; S. 2½ E., 7; N. ½ E., 10·3; N. ¼ W., 6′ current course. D. lat. 1·5 N., dep. 61·3 E.; course N. 89° E., dist. 61′. Lat. in 54° 8′·5 N.; diff. long. 104′. Long. in 1° 39′ E.

4. True Courses.—S. $4\frac{1}{2}$ W., 14′ dep. course; S. $3\frac{1}{4}$ W., 22; S. $5\frac{3}{4}$ W., 22; N. $4\frac{1}{2}$ W., 23; N. $1\frac{1}{4}$ W., 18; S. $\frac{1}{4}$ W., 19; S. $6\frac{1}{4}$ W., 21; N. 1 W., 20′ current course. Diff. lat. 10·4 S., dep. 90·6 W.; course S. 84° W., dist. 91′. Lat. in 36° 53′ N., diff. long. $113\frac{1}{2}$′ W. Long. in 10° $53\frac{1}{2}$′ W.

5. True Courses.—S. $\frac{1}{4}$ W., 15′ dep. course; N. $6\frac{1}{2}$ W., 11·9; S. $6\frac{1}{4}$ E., 12·9; S. $\frac{3}{4}$ E., 25·4; N., 20·2; S. $7\frac{1}{2}$ W., 14·7; N. $1\frac{1}{2}$ W., 27; N. $1\frac{3}{4}$ E., 21′ current course. Diff. lat. 23·4 N., dep. 11·5 W.; course N. 26° W., dist. 26′. Lat. in 30° 22′ N., diff. long. 13′ W. Long. in 32° 41′ E.

6. True Courses.—N. $5\frac{1}{4}$ E., 25′ dep. course; S. $4\frac{3}{4}$ E., 9·4; N. $4\frac{1}{2}$ W., 13·5; S. $2\frac{3}{4}$ W., 13·1; N. $3\frac{1}{2}$ E., 12·8; N. $1\frac{3}{4}$ E., 7·8; S. $3\frac{3}{4}$ W., 7; S. $1\frac{3}{4}$ E., 2·8; N. $5\frac{1}{4}$ W., 2·4; S. $3\frac{1}{2}$ W., 22′·5 current course. Diff. lat. 2·1 S., dep. 2·4 E.; course S. 49° E., dist 3′. Lat. in 62° 11′ S., diff. long. 4′·5 E. Long. in 140° 21′·5 E.

7. True Courses.—N. $5\frac{3}{4}$ W., 15′ dep. course; N. $7\frac{3}{4}$ W., 25; S. 1 W., 23; S. $4\frac{3}{4}$ W., 19; N. $1\frac{1}{4}$ W., 9; S. $2\frac{1}{2}$ W., 19; S. 6 W., 16; N. $2\frac{1}{4}$ W., 13; N. $7\frac{1}{4}$ E., 9′ current course. Diff. lat. 27·4 S., dep. 81·1 W.; course S. 71° W., dist. 86′. Lat. in 58° 2′ N., diff. long. 153′ W. Long. in 8° 45′ W.

8. True Courses.—S. 3 E., 15′ dep. course; S. $\frac{1}{4}$ E., 8·8; N. $\frac{3}{4}$ E., 11; S. $4\frac{1}{4}$ E., 19; S. 7 E., 13; S. $5\frac{3}{4}$ E., 26; N. $5\frac{3}{4}$ E., 6·2; N. $6\frac{1}{2}$ W., 9·8; S. $6\frac{1}{2}$ E., 21·8; N. $2\frac{1}{4}$ E., 12·1; S. $4\frac{1}{2}$ W., 60′ current course. Diff. lat. 64·8 S., dep. 36·6 E.; course S. $29\frac{1}{2}$° E., dist. $74\frac{1}{2}$′. Lat. in 35° 55′ S., diff. long. 45′ E. Long. in 20° 46′ E.

9. True Courses.—S. $3\frac{3}{4}$ W., 17′ dep. course; S. $1\frac{1}{4}$ W., 10·7; N. $6\frac{1}{2}$ W., 8·7; S. $5\frac{3}{4}$ W., 16·5; S. $5\frac{1}{2}$ W., 18·8; S. $5\frac{1}{2}$ E., 16; S. $4\frac{3}{4}$ W., 8·7; N. 6 E., 8·6; S. 3 W., 11; S. $3\frac{3}{4}$ W., 9·1; S. 1 E., 6·6; S. $\frac{1}{4}$ E., 6·7; S. $2\frac{3}{4}$ W., 35′ current course. Diff. lat. 104·9 S., dep. 67·3 W.; course S. 33° W., dist. 125′. Lat. in 2° 24′ S., diff. long. 68′ W. Long. in 0° 11′ W.

10. True Courses.—S. $7\frac{1}{2}$ E., 13′ dep. course; S. 7 E., 30·9; S. 2 W., 10·5; N. 2 E., 14·4; S. $1\frac{1}{4}$ E., 12; S. $3\frac{3}{4}$ E., 16·1; S. 6 E., 8·4; S. $6\frac{1}{2}$ E., 26·8; S. $7\frac{3}{4}$ E., 19·6; N. $7\frac{3}{4}$ E., 48′ current course. Diff. lat. 36·8 S., dep. 159·3 E.; course S. 77° E., dist. 164′. Lat. in 38° 19′ S., diff. long. 202′ E. Long. in 182° 2′ E., or 177° 58′ W.

11. True Courses.—N. 50° W., 19′ dep. course; N. 89 W., 19·4; N. 50 W., 22·7; S. 32 W., 25·7; S. 49 W., 15·9; S. 68 W., 8·9; S. 43 W., 18·9; S. 19 E., 6; N. 44 W., 11·4; N. 86 W., 7·3; S. 66 W., 24′ current course. Diff. lat. 29·0 S., dep. 133·3 W.; course S. 78° W., dist. 136′. Lat. in 34° 18′ S., diff. long. 161′ W. Long. in 83° 35′ W.

12. Magnetic Courses *(Corrected for Leeway only)*.—S. $5\frac{3}{4}$ E., 13′ dep. course; S. 7 W., 8·8; N. $7\frac{3}{4}$ W., 5·8; S. $4\frac{1}{2}$ W., 5·0; S. $4\frac{3}{4}$ W., 2·0; S. $1\frac{1}{2}$ W., 8·2; S. $1\frac{1}{4}$ E., 16; N. $\frac{3}{4}$ E., 9·8; N. $\frac{1}{4}$ W., 3; N. 1 W., 2·3; N. 4 W., 4·5; S. 6 W., 4·5; S. 3 W., 2; S. $2\frac{1}{2}$ W., 2·3. Diff. lat. 22·0 S., dep. 15·4 W.; compass course S. 35° W., dist. 27′. The variation 24° W. allowed to the *left* of S. 35° W., gives True Course S. 11° W. True course S. 11° W., and dist. 27′, give (Table 2) diff. lat. 26·5 S., dep. 5·2 W. Lat. in 26° 5′·5 S., diff. long. 6′ W. Long. in 45° 1′ E.

ASTRONOMICAL DATES, *Page* 114.

1. Jan.	$1^d\,16^h\,38^m\,9^s$	2. Feb.	$27^d\,8^h\,12^m\,0^s$	3. August	$14^d\,6^h\,28^m\,40^s$
4. Mar.	31 19 54 19	5. June	3 16 18 3	6. August	31 20 10 52
7. Dec.	31 6 18 34	8. July	1 8 3 24	9. June	30 23 30 10
10. Oct.	1 0 10 12	11. Dec. 1864,	31 20 9 50	12. Dec. 1865,	31 12 44 12

DEGREES INTO TIME, *Page* 115.

1.	$1^h 15^m 36^s$	2.	$4^h 30^m 48^s$	3.	$0^h\ 3^m 34{\cdot}4^s$	4.	$0^h 36^m 56^s$
5.	7 14 28	6.	0 0 54	7.	0 50 43·0	8.	5 5 22
9.	3 16 17·3	10.	10 52 11·2	11.	0 41 48·9	12.	3 24 40·8
13.	9 9 48	14.	0 5 40	15.	0 1 47·2	16.	0 2 29·6
17.	0 9 56	18.	10 27 28	19.	6 24 43·0	20.	9 22 8·7
21.	0 56 10	22.	0 9 12·8	23.	5 38 50·0	24.	11 55 19·0

TIME INTO DEGREES, *Page* 116.

1.	18° 28′ 0″	2.	58° 1′ 0″	3.	10° 33′ 0″	4.	168° 50′ 15″
5.	31 49 45	6.	147 24 30	7.	8 44 33	8.	25 15 24
9.	46 7 0	10.	124 16 30	11.	5 22 43·5	12.	175 16 40
13.	0 58 0	14.	2 29 0	15.	0 13 0	16.	5 10 15
17.	9 14 0	18.	75 12 45	19.	179 59 15	20.	0 28 0

GREENWICH DATES, *Page* 118.

1.	Jan. $6^d\ 8^h\ 8^m\ 0^s$	2.	Feb. $12^d 22^h\ 4^m 19^s$	3.	Jan. $31^d\ 7^h 29^m 28^s$
4.	Mar. 15 8 8 6	5.	April 10 10 30 5	6.	May 15 6 6 0
7.	May 31 21 34 58	8.	Oct. 31 21 22 10	9.	Dec. 1 6 32 45
10.	June 30 16 36 52	11.	Aug. 11 23 50 22	12.	Sept. 1 6 24 11
13.	Dec. 27 23 19 30	14.	July 8 at noon.	15.	Jan. 31 13 45 20
16.	May 31 18 24 40	17.	Mar. 2 0 5 40	18.	Aug. 31 23 26 40
19.	Oct. 31 19 35 40	20.	1865, Dec. 31 14 3 20		

SUN'S DECLINATION, *Pages* 122—123.

1.	20° 12′ 48″ S.	2.	12° 16′ 52″ S.	3.	5° 6′ 4″ N.	4.	0° 10′ 42″ N.
5.	17 10 29 N.	6.	22 4 0 N.	7.	23 27 10 N.	8.	0 6 33 N.
9.	18 56 27 N.	10.	12 37 44 N.	11.	0 2 39 N.	12.	3 6 37 S.
13.	21 43 1 S.	14.	23 27 10 S.	15.	23 2 21 S.	16.	0 0 42 N.
17.	22 34 25 S.	18.	16 37 47 S.	19.	4 12 23 N.	20.	2 10 10 N.
21.	9 43 15 N.	22.	19 10 15 N.	23.	14 40 53 N.	24.	18 52 45 N.
25.	23 2 35 N.	26.	14 34 57 S.	27.	8 25 26 N.	28.	3 16 39 S.
		29.	23 19 47 S.	30.	18 19 26 S.		

EQUATION OF TIME, *Page* 127.

1.	$+\ 6^m\ 3{\cdot}6^s$	2.	$+\ 14^m\ 6{\cdot}8^s$	3.	$+\ 6^m 19{\cdot}9^s$	4.	$+\ 0^m\ 4{\cdot}6^s$
5.	− 3 45·9	6.	− 0 1·1	7.	+ 2 28·9	8.	+ 5 44·1
9.	− 0 9·2	10.	− 2 30·7	11.	− 11 51·5	12.	+ 0 3·2
13.	+ 0 7·8	14.	− 0 5·1	15.	− 3 53·3	16.	− 0 0·1
17.	− 15 13·2	18.	+ 6 5·0	19.	+ 0 20·8	20.	− 15 58·2
21.	− 16 18·3	22.	0 0	23.	− 0 0·8	24.	+ 3 35·1

TRUE ALTITUDES, *Page* 130.

1.	17° 52′ 42″	2.	48° 17′ 11″	3.	30° 2′ 9″	4.	76° 14′ 16″	5.	58° 48′ 28″
6.	28 57 9	7.	65 13 4	8.	85 22 51	9.	28 23 26	10.	67 54 24
11.	14 17 14	12.	11 45 27	13.	69 45 25	14.	8 45 8	15.	19 57 40

MERIDIAN ALTITUDES, *Page* 135.

NO.	GREEN. DATE.	RED. DECL.	TRUE ALT.	LATITUDE.	BY RAPER: TRUE ALT.	BY RAPER: LATITUDE.
1.	10ᵈ 3ʰ 19ᵐ 24ˢ	21° 53′ 27″ S.	68° 57′ 22″	42° 56′ 5″ S.	68° 57′ 18″	42° 56′ 9″ S.
2.	31 21 20 36	17 1 54 S.	72 58 6	0 0 0 N.	72 58 3	0 0 3 N.
3.	7 18 0 48	4 51 10 S.	51 57 59	33 10 51 N.	51 57 51	33 10 59 N.
4.	28 11 1 32	14 23 11 N.	82 35 15	6 58 26 N.	82 35 8	6 58 19 N.
5.	1 21 51 48	15 26 17 N.	45 57 1	59 29 16 N.	45 56 56	59 29 21 N.
6.	10 19 48 12	23 6 6 N.	42 37 28	24 16 26 S.	42 37 25	24 16 29 S.
7.	20 10 26 32	20 32 56 N.	52 7 9	17 19 55 S.	52 6 58	17 20 7 S.
8.	19 5 30 0	12 37 44 N.	57 50 46	44 46 58 N.	57 50 45	44 46 59 N.
9.	25 17 51 48	10 25 23 N.	35 48 58	43 45 39 S.	35 48 55	43 45 43 S.
10.	22 12 54 0	0 0 12 N.	41 42 33	48 17 39 N.	41 42 23	48 17 49 N.
11.	23 6 0 48	11 36 6 S.	54 51 19	23 32 35 N.	54 51 12	23 32 42 N.
12.	14 18 39 16	18 31 11 S.	67 56 49	3 32 0 N.	67 56 40	3 32 9 N.
13.	9 20 18 40	22 56 32 S.	26 4 46	40 58 42 N.	26 4 35	40 58 53 N.
14.	20 19 59 56	0 40 4 N.	56 37 9	32 42 47 S.	56 37 4	32 42 52 S.
15.	20 14 24 0	0 12 17 N.	61 58 9	28 14 8 N.	61 58 0	28 14 17 N.
16.	7 9 19 0	7 5 23 N.	90 13 40	6 51 43 N.	90 13 40	6 51 43 N.
17.	16 3 1 44	19 11 45 N.	86 50 41	16 2 26 N.	86 50 34	16 2 19 N.
18.	22 17 57 0	0 4 43 S.	83 52 20	6 2 57 N.	83 52 14	6 3 3 N.
19.	2 16 56 0	15 14 31 S.	70 42 48	34 21 43 S.	70 42 44	34 21 47 S.
20.	22 11 35 52	0 1 28 N.	71 34 38	18 26 50 N.	71 34 32	18 26 56 N.
21.	12 0 32 48	13 34 3 S.	30 4 42	46 21 15 N.	30 4 36	46 21 21 N.
22.	20 1 58 0	0 0 0	77 7 26	12 52 34 S.	77 7 24	12 52 36 S.
23.	31 15 37 52	23 1 56 S.	54 38 7	12 19 57 N.	54 38 6	12 19 58 N.
24.	30 19 14 40	3 13 5 S.	81 37 16	11 35 49 S.	81 37 12	11 35 53 S.

AMPLITUDES, *Page* 141.

NO.	GREEN. DATE.	RED. DECL.	TRUE AMP.	VARIATION.
1.	Jan. 26ᵈ 19ʰ 47ᵐ 17ˢ	18° 24′ 50″ S.	E. 22° 53′ 26″ S.	22° 6′ 34″ W.
2.	Feb. 17 4 7 28	11 48 3 S.	W. 14 26 54 S.	8 3 6 E.
3.	Mar. 29 2 20 20	3 32 20 N.	E. 3 55 57 N.	23 37 12 W.
4.	April 4 9 53 0	6 7 33 N.	W. 6 32 5 N.	6 32 5 E.
5.	Mar. 4 19 50 0	5 59 15 S.	E. 7 56 55 S.	28 36 50 W.
6.	May 25 16 44 0	21 7 33 N.	E. 35 15 35 N.	35 15 35 W.
7.	June 2 9 56 26	22 16 52 N.	W. 38 31 21 N.	37 24 54 W.
8.	July 14 2 15 42	21 38 40 N.	E. 24 56 20 N.	11 37 25 E.
9.	Aug. 27 3 18 44	9 56 7 N.	W. 10 39 18 N.	23 5 42 W.
10.	Sept. 7 21 37 0	5 38 20 N.	E. 6 11 33 N.	6 11 33 W.
11.	Oct. 1 5 29 50	3 23 2 S.	E. 4 36 33 S.	18 40 18 E.
12.	Sept. 22 13 7 0	0 0 0	East.	0 0 0
13.	Nov. 2 21 27 40	15 8 5 S.	W. 17 25 38 S.	2 15 37 E.
14.	Dec. 3 21 13 45	22 16 51 S.	W. 36 7 54 S.	16 26 39 W.
15.	Mar. 20 1 57 52	0 0 0	West.	39 22 30 W.
16.	Sept. 22 13 7 0	0 0 0	West.	0 0 0
17.	June 18 18 41 24	23 26 15 N.	E. 23 26 15 N.	17 48 45 W.
18.	Feb. 25 22 31 52	8 36 39 S.	E. 18 39 1 S.	48 50 59 W.
19.	April 30 15 43 40	15 3 40 N.	W. 16 39 24 N.	13 50 39 E.
20.	May 27 17 32 12	21 28 0 N.	W. 32 54 59 N.	21 39 59 E.
21.	June 15 19 27 20	23 21 46 N.	E. 35 56 32 N.	27 30 32 W.
22.	Mar. 6 6 5 20	5 26 6 S.	W. 6 22 16 S.	23 14 46 W.
23.	Sept. 30 14 46 48	3 8 45 S.	E. 4 14 46 S.	7 0 14 W.
24.	June 1 5 31 20	22 7 45 N.	W. 38 13 38 N.	24 9 53 E.

TIDES, *Page* 146.

1.	$9^h 19^m$ A.M.	$9^h 56^m$ P.M.	2.	$8^h 58^m$ A.M.	$9^h 42^m$ P.M.
3.	1 31 „	1 49 „	4.	0 2 „	0 41 „
5.	11 37 „	—— „	6.	Noon.	—— „
7.	Noon.	—— „	8.	8 42 „	9 11 „
9.	6 23 „	7 4 „	10.	1 39 „	2 20 „
11.	10 4 „	10 20 „	12.	11 54 „	—— „
13.	10 25 „	10 50 „	14.	8 34 „	9 7 „
15.	11 38 „	11 55 „	16.	0 39 „	1 1 „
17.	3 16 „	3 38 „	18.	—— „	0 24 „
19.	6 47 „	7 9 „	20.	—— „	0 21 „

TIDES (Admiralty Tide Tables), *Page* 148.

1.	$9^h 2^m$ A.M.	$9^h 26^m$ P.M.	2.	$6^h 39^m$ A.M.	$7^h 13^m$ P.M.
3.	10 46 „	11 27 „	4.	—— „	0 6 „
5.	11 55 „	—— „	6.	—— „	0 25 „
7.	11 11 „	11 45 „	8.	—— „	0 6 „
9.	11 47 „	—— „	10.	11 32 „	—— „
11.	Noon.	—— „	12.	11 59 „	—— „
13.	Noon.	—— „	14.	11 49 „	—— „
15.	Noon.	—— „	16.	11 52 „	—— „
17.	——	0 13 „	18.	3 56 „	4 18 „
19.	11 50 „	—— „	20	11 24 „	11 40 „
21.	10 7 „	10 26 „	22.	Noon.	—— „
23.	11 51 „	—— „	24.	11 57 „	—— „

TIDES, *Page* 150.

1.	$6^h 10^m$ A.M.	$6^h 33^m$ P.M.	2.	$5^h 32^m$ A.M.	$5^h 48^m$ P.M.
3.	10 33 „	11 8 „	4.	8 16 „	8 55 „

TIDES (Method III), *Page* 155.

1.	$8^h 52^m$ A.M.	$9^h 13^m$ P.M.	2.	$5^h 3^m$ A.M.	$5^h 30^m$ P.M.
3.	11 36 „	Midnight.	4.	1 8 „	1 36 „
5.	11 50 „	——	6.	11 35 „	—— „

GREENWICH DATE BY CHRONOMETER, *Page* 157.

NO.	ACC. RATE.	GREEN. DATE.	NO.	ACC. RATE.	GREEN. DATE.
1.	$8^m 3.2^s$	Feb. $16^d 7^h 53^m 5^s$	2.	$2^m 35.9^s$	April $19^d 4^h 29^m 6^s$
3.	7 21.4	May 7 6 6 0	4.	3 11.1	June 25 20 56 30
5.	7 37.7	Oct. 25 8 35 42	6.	5 22	Jan. 19 12 33 0
7.	8 3	Nov. 8 16 27 0	8.	8 59.4	Aug. 1 0 5 55.4
9.	1 25.91	May 1 13 28 0			

HOUR-ANGLE, *Page* 159.

1.	$4^h 26^m 34^s$	2.	$2^h 50^m 42^s$	3.	$4^h 50^m 20^s$	4.	$4^h 6^m 56^s$	5.	$3^h 51^m 23^s$
6.	4 6 53	7.	2 33 42	8.	4 3 50.2	9.	4 29 56	10.	3 29 20

CHRONOMETERS, *Pages* 167—168.

NO.	GREEN. DATE.	RED. DECL.	TRUE ALT.	EQ. TIME.	HOUR-ANGLE.	LONGITUDE.
1.	Jan. $1^{d}\ 19^{h}\ 30^{m}\ 35^{s}$	22° 54′ 42″ S.	49° 19′ 18″	+ $4^{m}\ 23^{s}$	$2^{h}\ 58^{m}\ 18^{s}$	23° 52′ 30″ E.
2.	Feb. 18 19 45 57	11 13 9 S.	21 34 14	+14 5	4 45 7	138 18 45 E.
3.	Mar. 27 23 25 48	3 6 4 N.	30 21 8	+ 5 7·5	3 43 52	65 48 0 E.
4.	April 5 19 13 47	6 29 34 N.	16 17 11	+ 2 28	4 45 44	0 44 15 E.
5.	April 30 18 54 3	15 6 6 N.	28 18 45	— 3 1	4 20 4	140 45 0 E.
6.	June 14 17 56 42	23 19 17 N.	39 50 48	+ 0 5	3 26 31	39 13 0 E.
7.	July 5 0 33 8	22 46 38 N.	48 47 5	+ 4 15	3 0 12	52 16 15 W.
8.	Aug. 13 2 20 42	14 34 38 N.	27 23 29	+ 4 34	2 59 42	78 57 30 W.
9.	Aug. 31 19 12 18	8 16 4 N.	44 44 41	— 0 8	2 37 44	111 19 30 E.
10.	Oct. 25 8 35 42	12 20 9 S.	40 31 1	—15 33	2 30 0	95 23 45 W.
11.	Nov. 27 7 13 53	21 15 16 S.	34 50 6	—12 0	4 6 55	173 12 0 W.
12.	Dec. 24 16 31 52	23 24 27 S.	10 42 56	+ 0 19	5 30 14	29 33 15 E.
13.	Jan. 1 14 0 38	22 55 56 S.	39 9 31	+ 4 16	3 49 23	151 44 45 W.
14.	Feb. 10 21 33 26	13 56 40 S.	12 17 54	+14 31	3 2 50	5 26 15 W.
15.	Oct. 25 0 26 10	12 33 43 S.	25 10 24	—15 56·5	3 28 35	62 40 30 W.
16.	Feb. 5 23 59 40	15 30 42 S.	21 21 7	+14 24	4 22 2	69 11 30 E.
17.	April 20 15 48 56	11 50 37 N.	32 22 15	— 1 19	3 49 7	179 30 24 W.
18.	Aug. 21 8 22 2	11 55 35 N.	34 2 1	+ 2 49	3 40 26	179 35 21 E.
19.	Mar. 20 1 57 46	0 0 7 S.	29 2 39	+ 7 32	4 3 49	88 29 15 W.
20.	June 14 11 6 16	23 18 32 N.	30 49 32	+ 0 2	1 53 42	165 1 0 E.
21.	Mar. 21 3 27 42	0 25 3 N.	33 9 28	+ 7 13	2 50 6	92 38 45 W.

TRUE AZIMUTHS, *Page* 170.

1. S. 98° 39′ 38″ E.
2. S. 41° 58′ 18″ E.
3. N. 69° 38′ 38″ W.
4. S. 75 58 4 W.
5. S. 90 32 54 E.
6. S. 60 9 38 E.
7. S. 49 18 24 W.
8. S. 60 3 6 W.
9. S. 56 3 30 W.
10. East.
11. N. 84 5 0 W.
12. S. 60 3 6 W.
13. N. 89 46 49 E.
14. S. 103 39 11 W.

AZIMUTHS, *Page* 176.

NO.	GREEN. DATE.	RED. DECL.	TRUE ALT.	LOGS.	TRUE AZIMUTH.	VARIATION.
1.	$23^{d}\ 23^{h}\ 46^{m}\ 7^{s}$	19° 7′ 43″ S.	38° 34′ 32″	19·730879	N. 94° 22′ 20″ E.	4° 22′ 20″ E.
2.	28 9 43 4	7 41 4 S.	27 7 43	19·296540	S. 52 49 56 W.	10 13 56 E.
3.	27 0 34 12	2 43 44 N.	29 41 3	19·703908	S. 90 39 18 W.	4 58 12 W.
4.	2 19 0 8	5 20 57 N.	11 50 43	19·652405	S. 84 9 52 W.	8 19 52 E.
5.	26 21 9 32	21 19 41 N.	43 19 41	19·418763	S. 61 36 42 E.	25 36 42 W.
6.	20 6 55 44	23 27 7 N.	16 49 1	19·808286	S. 106 37 54 W.	23 2 6 W.
7.	31 1 6 46	18 12 36 N.	43 35 48	19·600897	S. 78 22 16 E.	9 0 16 W.
8.	23 2 57 38	11 19 36 N.	7 43 28	19·758753	S. 98 29 12 E.	25 10 48 E.
9.	31 18 33 2	8 16 39 N.	30 14 50	19·556656	N. 73 47 22 W.	3 28 37 W.
10.	25 7 30 28	20 53 10 S.	34 2 21	19·696885	N. 89 43 30 W.	9 26 30 E.
11.	16 22 58 2	23 22 49 S.	51 13 0	19·712212	N. 91 46 28 E.	8 53 32 W.
12.	2 16 18 50	22 58 55 N.	14 19 37	19·259270	N. 50 27 22 E.	11 32 38 W.
13.	6 2 49 30	22 26 53 S.	26 46 47	19·732554	N. 94 36 42 W.	29 56 42 W.
14.	25 1 43 33	13 18 35 N.	18 52 56	19·438802	N. 63 12 46 E.	14 37 14 W.
15.	29 6 53 47	17 45 39 S.	13 47 28	19·243082	S. 49 27 40 W.	23 32 20 W.
16.	1 2 22 23	16 58 28 S.	40 7 21	19·650544	N. 83 56 36 W.	26 46 36 W.
17.	26 0 29 58	2 20 10 N.	32 50 59	19·363968	S. 57 28 42 E.	22 58 42 W.
18.	25 15 40 0	8 43 17 S.	60 48 32	19·425109	S. 62 6 48 W.	10 21 48 E.
19.	20 19 3 20	23 27 13 N.	15 46 28	19·841771	S. 112 54 22 E.	62 54 22 W.
20.	10 20 16 0	4 31 22 N.	42 38 43	18·933854	N. 34 4 48 E.	10 45 12 W.
21.	31 21 25 30	23 0 48 S.	45 22 20	19·345856	S. 56 11 8 E.	22 26 8 W.

REDUCTION TO MERIDIAN, *Pages* 185—187.

NO.	GREEN. DATE.	TIME NOON.	RED. DECL.	TRUE ALT.	NAT. NO.	LATITUDE.
1.	Jan. 4ᵈ 1ʰ 34ᵐ 40ˢ	14ᵐ 8ˢ	22° 41′ 11″ S.	32° 26′ 19″	1442	34° 46′ 37″ N.
2.	Feb. 28 1 4 49	14 45	7 49 3 S.	38 6 33	1481	43 57 56 N.
3.	March 20 16 34 18	25 42	0 14 25 N.	47 57 15	4710	41 24 4 S.
4.	April 20 23 16 56	18 40	11 56 56 N.	61 39 1	2488	39 59 48 N.
5.	May 29 7 38 27	30 27	21 42 53 N.	30 33 7	6517	37 17 55 S.
6.	June 19 0 41 12	15 8	23 26 29 N.	68 48 28	1427	44 24 23 N.
7.	July 16 0 2 9	10 19	21 20 27 N.	67 52 44	942	0 38 2 S.
8.	Aug. 29 15 2 44	20 24	9 3 3 N.	57 34 6	2945	41 9 59 N.
9.	Sept. 8 12 15 45	9 43	5 24 31 N.	85 30 35	883	9 11 58 N.
10.	Oct. 10 18 47 58	28 10	7 2 58 N.	36 44 4	5214	45 50 34 N.
11.	Nov. 2 17 1 29	20 5	15 4 35 S.	72 2 22	3142	32 26 38 S.
12.	Dec. 23 1 18 58	29 14	23 26 29 S.	65 23 36	5050	47 20 37 S.
13.	Jan. 5 8 58 28	17 32	22 32 14 S.	58 17 34	2670	8 52 40 N.
14.	April 28 1 54 11	22 37	14 13 7 N.	56 30 3	4466	18 48 51 S.
15.	July 13 9 46 59	22 21	21 44 52 N.	13 26 24	2557	54 39 42 S.
16.	*March 20 1 57 16	16 56	0 0 1 S.	70 30 47	2580	19 2 19 S.
17.	April 11 10 46 29	10 19	8 57 10 N.	80 42 18	990	0 1 10 N.
18.	Sept. 15 14 29 20	22 0	2 41 50 N.	44 19 3	3385	42 42 49 S.
19.	March 15 19 49 1	4 9	1 40 51 S.	50 12 46	131	38 5 41 N.
20.	Dec. 31 0 40 46	10 46	23 4 55 S.	14 54 41	625	51 58 11 N.
21.	March 4 19 8 4	20 4	5 59 56 S.	50 0 56	3151	33 42 14 N.
22.	Sept. 22 7 4 42	22 6	0 5 53 N.	43 55 22	3240	45 43 15 S.
23.	Dec. 23 0 48 31	29 55	23 26 31 S.	23 53 10	5776	42 18 34 N.

BY TOWSON:

NO.	AUG. I.	INDEX.	AUG. II.	LATITUDE.
1.	+ 2′ 21″	21	+ 3′ 23″	34° 46′ 46″ N.
2.	+ 0 58	26½	+ 6 13	43 57 13 N.
3.	+ 0 11	68	+ 24 11	41 23 58 S.
4.	+ 2 21	41½	+ 20 21	39 59 55 N.
5.	+ 10 32	77	+ 15 38	37 17 50 S.
6.	+ 2 44	24	+ 16 27	44 24 18 N.
8.	+ 2 6	50	+ 20 55	41 10 8 N.
10.	+ 3 8	75½	+ 19 3	45 49 47 N.
11.	+ 3 19	47	+ 38 56	32 26 36 S.
12.	This hour-angle exceeds the limits of the table.			
14.	Do.		do.	
15.	+ 5 42	54	+ 3 32	54 39 30 S.
18.	+ 0 45	57	+ 15 49	42 42 33 S.
21.	+ 1 23	49½	+ 15 37	33 42 8 N.
23.	+ 10 36	73	+ 10 41	42 19 2 N

MERIDIAN ALTITUDE OF STAR, *Page* 189.

NO.	STAR'S DECL.	LATITUDE.	NO.	STAR'S DECL.	LATITUDE.
1.	28° 21′ 13″ N.	43° 15′ 16″ N.	2.	45° 51′ 22″ N.	9° 45′ 12″ N.
3.	38 40 0 N.	1 24 58 S.	4.	49 22 56 N.	11 9 45 N.
5.	10 27 34 S.	16 19 8 N.	6.	57 55 2 S.	8 0 39 S.
7.	14 26 24 N.	26 14 58 N.	8.	22 49 41 N.	1 5 35 N.
9.	16 41 1 N.	43 53 50 S.	10.	62 21 27 S.	47 26 26 S.
11.	8 4 51 S.	51 38 41 N.	12.	44 48 12 N.	25 4 35 S.
13.	8 31 17 N.	20 43 7 S.	14.	16 32 22 S.	47 37 13 S.
15.	19 52 59 N.	30 10 21 N.	16.	26 7 47 S.	4 50 38 S.
17.	60 16 31 S.	19 50 57 N.	18.	30 19 55 S.	50 16 40 S.
19.	14 28 47 N.	42 14 46 S.	20.	55 48 2 N.	28 0 40 N.

EXAMINATION PAPER—No. I, *Pages* 190—191.

1. Log. 5·501368 = Nat. No. 317226 nearly. (The product.)
2. Log. 2·385606 = Nat. No. 243·0 nearly. (The quotient.)
3. TRUE COURSES.—S. $2\frac{1}{4}$ W., 15′ dep. course; S. $3\frac{1}{2}$ W., 21; N. $5\frac{1}{4}$ W., 21; N. $3\frac{1}{4}$ W., 18; N. $5\frac{3}{4}$ W., 15; S. $2\frac{1}{2}$ W., 13; S. 6 W., 17; S. $3\frac{3}{4}$ W., 8. *Diff. lat.* 22′·0; *dep.* 89′·2 W.; *course* S. 76° W.; *dist.* 92′. *Lat. in* 36° 41′ N. *Long. in* 10° 52′ W.
4. Green. date, Jan. $1^d\ 7^h\ 18^m\ 44^s$; red. decl. 22° 57′ 25″ S.; true alt. 60° 12′ 47″. *Latitude* 6° 49′ 48″ N.

By Raper: True alt. 60° 12′ 38″. *Latitude* 6° 49′ 57″ N.

5. Log. of diff. long. 2·394015 = *Diff. long.* 247′·8.
6. Diff. lat. 176′ S.; mer. diff. lat. 319′; diff. long. 517′ W.; log. tang. of course 10·209699; *course* S. 58° 19′ 28″ W.; log. of distance 2·525263; *distance* 335′·2.
7. $1^h\ 37^m$ A.M.; $2^h\ 8^m$ P.M.

7*a*. $4^h\ 40^m$ A.M.; $5^h\ 12^m$ P.M. (Method II.)

7*b*. $7^h\ 36^m$ A.M.; $8^h\ 2^m$ P.M. (Method III.)

8. Green. date $1^d\ 5^h\ 23^m\ 24^s$; red. decl. 22° 57′ 51″ S.; log. sine true amp. 9·788033. True amp. E. 37° 51′ 55″ S. *Variation* 23° 48′ 10″ E.
9. Green. date $29^d\ 6^h\ 53^m\ 49^s$; red. decl. 17° 45′ 39″ S.; true alt. 13° 47′ 28″; hour-angle $3^h\ 23^m\ 13^s$; red. eq. time *add* $13^m\ 32^s$; mean time ship $29^d\ 3^h\ 36^m\ 45^s$. *Longitude* 49° 16′ 0″ W.

Raper: True alt. 13° 47′ 13″; hour-angle $3^h\ 23^m\ 15^s$. *Longitude* 49° 15′ 30″ W.

10. Green. date $15^d\ 6^h\ 11^m\ 12^s$; red. decl. 21° 1′ 2″ S.; true alt. 55° 18′ 24″; sum of logs. 19·722335; true azimuth N. 93° 10′ 6″ E. *Variation* 6° 10′ 6″ E.

By Raper: True alt. 55° 18′ 22″; sin. sq. of azimuth 9·722337; true azimuth N. 93° 10′ 7″ E. *Variation* 6° 10′ 7″ E.

11. Time from noon $16^m\ 47^s$; Green. date $16^d\ 14^h\ 18^m\ 55^s$; red. decl. 20° 45′ 28″ S.; true alt. 33° 7′ 1″; nat. cos. mer. zen. dist. 548376; mer. zen. dist. 56° 44′ 40″ N. *Latitude* 35° 59′ 12″ N.

Raper: True alt. 33° 6′ 59″; 1st red. + 8′ 18″; 2nd red. − 1″. *Latitude* 35° 59′ 16″ N.
Towson: Aug. I, 3′ 3″; index 30; aug. II, 5′ 10″. *Latitude* 35° 59′ 18″ N.

12. Star's decl. 16° 14′ 1″ N.; true alt. 52° 30′ 36″. *Latitude* 53° 43′ 25″ N.

Raper: True alt. 52° 30′ 32″. *Latitude* 53° 43′ 29″ N.

13. N. 27° 32′ W.; N. 0° 22′ W.; N. 38° 59′ E.

EXAMINATION PAPER—No. II, *Pages* 191—193.

1. 3·573829 = 3748·25. (The product.)
2. 1·168523 = 14·7409. (The quotient.)
3. TRUE COURSES.—N. $3\frac{1}{2}$ E., 18′ dep. course; S. $7\frac{1}{2}$ E., 29; S. 6 E., 26; N. $3\frac{1}{2}$ E., 22; N. 2 E., 18; S. $2\frac{1}{2}$ E., 15; S. $4\frac{1}{2}$ E., 21; S. $3\frac{1}{2}$ E., 12′ current course. *Diff. lat.* 1·9; *dep.* 115·5; *course* S. 89° E.; *dist.* $115\frac{1}{2}$′. *Lat. in* 47° 29′ N.; *diff. long.* 171′ E. *Long. in* 49° 42′ W.
4. Green. date, Jan. $31^d\ 18^h\ 47^m\ 4^s$; red. decl. 17° 3′ 43″ S.; true alt. 78° 17′ 52″. *Latitude* 5° 21′ 35″ S.

By Raper: True alt. 78° 17′ 50″. *Latitude* 5° 21′ 33″ S.

5. Log. of diff. long. 2·518908 = *Diff. long.* 330′·3.

6. Diff. lat. 2404′ S.; mer. diff. lat. 3104′; diff. long. 3692′; tang. course 10·075340; *course* S. 49° 56′ 42″ W.; log. of distance 3·572370; *distance* 3735′·6.

7. 3^h 41^m A.M.; 3^h 56^m P.M.

7*a*. 5^h 47^m A.M.; 6^h 9^m P.M. (Method II.)

7*b*. Semidiameter 15′ 9″; corr. + 20^m; 5^h 40^m A.M.; 6^h 5^m P.M. (Method III.)

8. Green. date 19^d 18^h 10^m 12^s; red. decl. 10° 52′ 54″ S.; true amp. W. 11° 7′ 35″ S. *Variation* 11° 22′ 25″ E.

9. Green. date 9^d 9^h 30^m 41^s; red. decl. 14° 26′ 5″ S.; true alt. 9° 14′ 2″; red. eq. time *add* 14^m 31^s; hour-angle 3^h 38^m 50^s. *Longitude* 166° 15′ E.

Raper: True alt. 9° 13′ 51″; hour-angle 3^h 38^m 51^s. *Longitude* 166° 14′ 45″ E.

10. Green. date 16^d 5^h 29^m 51^s; red. decl. 12° 8′ 3″ S.; true alt. 7° 15′ 55″; sum of logs. 19·402623; true azimuth S. 60° 21′ 28″ E. *Variation* 24° 1′ 28″ W.

Raper: True alt. 7° 15′ 43″; sine sq. 9·402729; true azimuth S. 60° 21′ 58″ E. *Variation* 24° 1′ 58″ W.

11. Time from noon 28^m 48^s; Green. date 14^d 19^h 54^m; red. decl. 12° 36′ 57″ S.; true alt. 46° 31′ 34″ N.; nat. cos. mer. zen. dist. 729995; zen. dist. 43° 6′ 50″ S. *Latitude* 55° 43′ 47″ S.

Raper: True alt. 46° 31′ 28″; 1st red. + 21′ 30″; 2nd red. — 4″; *Lat.* 55° 44′ 3″ S.

Towson: Aug. I, 5′ 47″; index 76½; aug. II, 27′ 45″. *Latitude* 55° 43′ 35″ S.

12. Star's decl. 5° 33′ 52″ N.; true alt. 77° 14′ 26″. *Latitude* 18° 19′ 26″ N.

Raper: True alt. 77° 14′ 16″. *Latitude* 18° 19′ 36″ N.

13. S. 11° 57′ E.; S. 60° 42′ W.

EXAMINATION PAPER—No. III, *Pages* 193—194.

1. 4·486380 = 30646·4. (The product.)

2. 1·875495 = 75·07. (The quotient.)

3. True Courses.—S. 6½ E., 17′ dep. course; S. 3 W., 20·7; S. 2½ W., 20; N. 4¾ W., 24; N. 4¾ W., 26; S. 7¾ E., 19; S. 3¼ E., 18; N. 4¾ E., 21. *Diff. lat.* 13·1 S.; *dep.* 1·6 E.; *course* S. 6° E.; *dist.* 14′. *Lat. in* 61° 47′ N.; *diff. long.* 3′ E. *Long. in* 150° 3′ E.

4. Green. date 20^d 11^h 33^m 12^s; red. decl. 0° 9′ 28″ N.; true alt. 89° 54′ 37″. *Latitude* 0° 4′ 5″ N.

Raper: True alt. 89° 54′ 32″. *Latitude* 0° 4′ 0″ N.

5. Log. of diff. long. 2·679550 = *Diff. long.* 478′·1.

6. Diff. lat. 688′ N.; mer. diff. lat. 786′; diff. long. 3625′ W.; *course* N. 77° 45′ 58″ W.; *distance* 3247′.

7. 1^h 13^m A.M.; 1^h 28^m P.M.

7*a*. 2^h 54^m A.M.; 3^h 29^m P.M. (Method II.)

7*b*. 0^h 49^m A.M.; 1^h 11^m P.M. (Method III.)

8. Green. date 5^d 20^h 16^m 16^s; red. decl. 5° 35′ 37″ S.; true amp. W. 9° 9′ 3″ S. *Variation* 0° 42′ 48″ W.

9. Interval 130^d 23^h; Green. date 30^d 22^h 53^m $12^s·5$; red. decl. 4° 15′ 27″ N.; true alt. 29° 19′ 55″; hour-angle 3^h 57^m 9^s; red. eq. time *add.* 4^m $12^s·1$; mean time ship 30^d 20^h 7^m 3^s. *Longitude* 41° 32′ 15″ W.

Raper: True alt. 29° 19′ 45″; hour-angle 3^h 57^m 10^s. *Longitude* 41° 32′ 15″ W.

10. Green. date 9^d 9^h 43^m 5^s; red. decl. 4° 12′ 34″ S.; true alt. 18° 6′ 51″; sum of logs. 19·603892; true azimuth N. 78° 39′ 38″ E. *Variation* 7° 17′ 8″ E.

Raper: True alt. 18° 6′ 43″; sine sq. 9·603914; true azimuth N. 78° 39′ 47″ E. *Variation* 7° 17′ 17″ E.

11. Time from noon $10^m\ 14^s$; Green. date $24^d\ 18^h\ 13^m\ 34^s$; red. decl. 1° 50′ 29″ N.; true alt. 71° 20′ 43″; nat. cos. mer. zen. dist. 948397; mer. zen. dist. 18° 29′ 12″ N. *Latitude* 20° 19′ 41″ N.

Raper: True alt. 71° 20′ 37″; 1st red. + 10′ 26″; 2nd red. — 3″. *Latitude* 20° 19′ 35″ N.

12. Star's decl. 19° 52 58″ N.; true alt. 36° 7′ 27″. *Latitude* 33° 59′ 35″ S.

Raper: True alt. 36° 7′ 22″. *Latitude* 33° 59′ 40″ S.

13. S. 70° 41′ W.; N. 84° 19′ E.

EXAMINATION PAPER—No. IV, *Pages* 194—196.

1. 4·106123 = 12768·0.
2. 2·513218 = 326·0.
3. True Courses.—S. $\frac{1}{2}$ W., 19; S. $7\frac{3}{4}$ W., 14; N. $1\frac{3}{4}$ E., 21·4; S. 3 E., 8·9; N. $5\frac{1}{2}$ W., 11·6; N. $4\frac{3}{4}$ E., 9·4; S. $5\frac{1}{2}$ W., 13·9; S. $5\frac{1}{2}$ W., 22·5. *Diff. lat.* 12·9 S.; *dep.* 38·5 W.; *course* S. $71\frac{1}{2}$° W.; *dist.* 41′. *Lat. in* 50° 25′ S.; *diff. long.* 60 W. *Long. in* 179° 20′ E.
4. Green. date $1^d\ 5^h\ 50^m\ 48^s$; red. decl. 4° 45′ 22″ N.; true alt. 48° 55′ 26″. *Latitude* 45° 49′ 56″ N.
5. Log. of diff. long. 2·364667 = *Diff. long.* 231·5.
6. Diff. lat. 325′ N.; mer. diff. lat. 552′; diff. long. 325′ W.; tang. course 9·769944; *course* N. 30° 29′ 17″ W.; *distance* 377·1 +.
7. $8^h\ 42^m$ A.M., $9^h\ 20^m$ P.M.

7*a*. $10^h\ 36^m$ A.M., $10^h\ 55^m$ P.M. (Method II.)

7*b*. $7^h\ 53^m$ A.M., $8^h\ 19^m$ P.M. (Method III.)

8. Green. date $27^d\ 23^h\ 18^m\ 50^s$; red. decl. 14° 14′ 4″ N.; true amp. W. 18° 15′ 51″ N. *Variation.* 15° 29′ 9″ W.
9. Acc. rate $15^m\ 36^s·9$; Green. date $14^d\ 22^h\ 9^m\ 3^s$; true alt. 26° 37′ 25″; red. decl. 9° 50′ 45″ N.; hour-angle $2^h\ 58^m\ 54^s$; mean time ship $15^d\ 26^h\ 58^m\ 54^s$. *Longitude* 72° 27′ 45″ E.
10. Green. date $17^d\ 2^h\ 43^m\ 25^s$; red. decl. 10° 37′ 11″ N.; true alt. 42° 20′ 39″; true az. S. 64° 10′ 58″ W. *Variation* 19° 49′ 2″ W.
11. Time from noon $28^m\ 38^s$; Green. date $18^d\ 11^h\ 38^m\ 34^s$; red. decl. 11° 5′ 51″ N.; true alt. 54° 20′ 16″; mer. zen. dist. 35° 8′ 20″ N. *Latitude* 46° 14′ 11″ N.
12. Star's decl. 10° 27′ 34″ S.; true alt. 20° 50′ 39″. *Latitude* 58° 41′ 47″ N.
13. S. 68° 11′ W.; S. 78° 10′ W.; N. 13° 1′ E.; S. 79° 16′ E.

EXAMINATION PAPER—No. V, *Pages* 196—197.

1. 4·838071 = 68876·5 +.
2. 2·826661 = 670·90 +.
3. True Courses.—S. 3 E., 12; S. $1\frac{1}{2}$ E., 12·3; S., 16; N. $5\frac{1}{2}$ W., 12·9; N. $7\frac{1}{4}$ E., 16·4; S. 6 W., 7·3; N. $3\frac{1}{4}$ E., 10·7; S. $3\frac{3}{4}$ W., 20·4; N. $4\frac{1}{2}$ E., 29. *Diff. lat.* 20·2 S.; *dep.* 23·5 E.; *course* S. 49° E.; *dist.* 31′. *Lat. in* 64° 22′ S.; *diff. long.* 53. *Long. in* 141° 14′ E.

4. Green. date $8^d\ 7^h\ 1^m\ 8^s$; red. decl. 17° 14′ 43″ N.; true alt. 76° 14′ 11″. *Lat.* 3° 28′ 54″ N.

5. Log. of diff. long. 2·992876 = *Diff. long.* 983·7.

6. Diff. lat. 732′ S.; mer. diff. lat. 881′; diff. long. 1098′ W.; *course* S. 51° 15′ 27″ W.; *distance* 1170′.

7. $8^h\ 41^m$ A.M., $9^h\ 13^m$ P.M. $11^h\ 51^m$ A.M., no P.M. No A.M., $0^h\ 3^m$ P.M.

7*a*. $10^h\ 53^m$ A.M., $11^h\ 14^m$ P.M. (Method II.)

7*b*. $1^h\ 2^m$ A.M., $1^h\ 24^m$ P.M. (Method III.)

8. Green. date $20^d\ 16^h\ 6^m\ 24^s$; red. decl. 20° 10′ 40″ N.; true amp. E. 29° 42′ 12″ N. *Variation* 32° 10′ 18″ E.

9. Green. date $21^d\ 20^h\ 59^m\ 21^s$; red. decl. 20° 25′ 8″ N.; red. eq. time *(subt.)* $3^m\ 36^s{\cdot}6$; true alt. 32° 19′ 31″; hour-angle $4^h\ 17^m\ 18^s$; mean time ship $21^d\ 19^h\ 39^m\ 5^s$. *Longitude* 20° 4′ W.

10. Green. date $25^d\ 9^h\ 53^m\ 51^s$; red. decl. 21° 4′ 36″ N.; true alt. 40° 54′ 26″; logs. 19·633828; true az. S. 81° 59′ 36″ W., or N. 98° 0′ 24″ W. *Var.* 10° 29′ 36″ E.

11. Time from noon $25^m\ 25^s$; red. decl. 17° 46′ 55″ N.; true alt. 43° 39′ 55″; nat. cos. mer. zen. dist. 45° 55′ 30″ S. *Latitude* 28° 8′ 35″ S.

Towson: Aug. I, + 6′ 12″; index 63½; aug. II, + 18′ 26″ *Lat.* 28° 8′ 32″ S.

12. Star's decl. 10° 27′ 35″ S.; zen. dist. 19° 53′ 44″ S. *Latitude* 30° 21′ 19″ S.

13. S. 58° 22′ E.; N. 27° 32′ W.; S. 58° 12′ W.; N. 52° 14′ E.

EXAMINATION PAPER—No. VI, *Pages* 197—199.

1. 5·707396 = Nat. No. 509795+. (The product.)

2. 2·645180 = Nat. No. 441·75+. (The quotient.)

3. True Courses.—S. 7¾ E., 22·5; N. 6¼ E., 24·9; N. 1¼ W., 14·7; N. 6¾ W., 10·6; N. 4 E., 18·2; S. 6¾ E., 12·7; N. 5¾ W., 11·9; N. 5½ W., 19·4; S. 1 W., 9; N. 1¾ E., 8·1; S. 3½ W., 16. *Diff. lat.* 34·6 N.; *dep.* 20·1 E.; *course* N. 30° E.; *dist.* 40′. *Lat. in* 56° 47′ N.; *diff. long.* 37′. *Long. in* 135° 3′ W.

4. Green. date $31^d\ 17^h\ 34^m\ 52^s$; red. decl. 22° 3′ 43″ N.; true alt. 75° 49′ 26″. *Latitude* 7° 53′ 9″ N.

5. Log. of diff. long. 2·487692 = *Diff. long.* 307·3+.

6. Diff. lat. 2181′ S.; mer. diff. lat. 2301′; diff. long. 3038′ W.; *course* S. 52° 51′ 34″ W. *distance* 3612′.

7. $4^h\ 32^m$ A.M., $5^h\ 3^m$ P.M. $11^h\ 32^m$ A.M., no P.M. No A.M., $0^h\ 24^m$ P.M. No A.M., $0^h\ 13^m$ P.M. $0^h\ 59^m$ A.M., $1^h\ 30^m$ P.M.

7*a*. $4^h\ 5^m$ A.M., $4^h\ 30^m$ P.M. No A.M., $0^h\ 16^m$ P.M. (Method II.)

7*b*. Correction — $1^h\ 4^m$, $5^h\ 0^m$ A.M., $5^h\ 26^m$ P.M. (Method III.)

8. Green. date $9^d\ 20^h\ 43^m$; red. decl. 23° 1′ 54″ N.; sine of true amp. 9·688390; true amp. W. 29° 12′ 25″ N. *Variation* 7° 21′ 20″ W.

9. Interval $45^d\ 21\frac{1}{2}^h$; Green. date $14^d\ 21^h\ 45^m\ 20^s$; red. decl. 23° 19′ 42″ N.; true alt. 28° 49′ 39″; red. eq. time $0^m\ 7^s{\cdot}2$ *additive*; hour-angle $3^h\ 49^m\ 4^s$; mean time ship $14^d\ 27^h\ 49^m\ 11^s$. *Longitude* 90° 57′ 45″ E.

10. Green. date $7^d\ 22^h\ 0^m\ 12^s$; red. decl. 22° 52′ 18″ N.; true alt. 31° 18′ 54″; true azimuth S. 107° 31′ 28″ E. *Variation* 14° 31′ 28″ W.

11. Time from noon $37^m\ 26^s$; Green. date $4^d\ 14^h\ 16^m\ 2^s$; red. decl. 22° 32′ 20″ N.; true alt. 50° 3′ 23″; mer. zen. dist. 39° 25′ 31″ N. *Latitude* 61° 57′ 51″ N.

Towson: Beyond the limits of the Tables.

12. Star's decl. 28° 20′ 48″ N.; true alt. 48° 33′ 47″. *Latitude* 13° 5′ 25″ S.

13. N. 65° 33′ W.; S. 89° 35′ E.; S. 19° 6′ E.; S. 43° 40′ W.

EXAMINATION PAPER—No. VII, *Pages* 199—200.

1. 4·141829 = Nat. No. 13862·1+.
2. 2·537819 = Nat. No. 345·0.
3. TRUE COURSES.—S. $\frac{1}{2}$ W., 17; S. $6\frac{3}{4}$ E., 22; S. $5\frac{1}{4}$ E., 6·5; N. $3\frac{1}{4}$ W., 5·8; S. $6\frac{1}{4}$ W., 26; S. 6 E., 17; S. 3 W., 27·4; S. $4\frac{1}{4}$ E., 14·6; S. $2\frac{1}{2}$ E., 15·8; N. $5\frac{1}{2}$ W., 9. *Diff. lat.* 78·5; *dep* 8·1; *course* S. 6° E.; *dist.* 79'. *Lat. in* 50° 6'·5 N.; *diff. long.* 13' E. *Long. in* 9° 16' W.
4. Green. date $26^d\ 0^h\ 49^m\ 16^s$; red. decl. 19° 23' 23" N.; true alt. 15° 46' 12". *Latitude* 54° 50' 25" S.
5. Log. of diff. long. 2·633861 = *Diff. long.* 430·4 nearly.
6. Diff. lat. 745' S.; mer. diff. lat. 1042; diff. long. 1292' W.; *course* S. 51° 6' 50" W.; *distance* 1187'.
7. $11^h\ 47^m$ A.M., no P.M.

7*a*. $5^h\ 21^m$ A.M., $5^h\ 45^m$ P.M. (Method II.)

7*b*. Correction + 24^m, $11^h\ 45^m$ A.M., no P.M. (Method III.)

8. Green. date $12^d\ 6^h\ 36^m\ 32^s$; red. decl. 21° 54' 46" N.; true amp. W. 25° 16' 16" N.; *Variation* 11° 17' 29" W.
9. Green. date $16^d\ 21^h\ 58^m\ 29^s$; red. decl. 21° 11' 15" N.; true alt. 13° 31' 22"; red. eq. time $5^m\ 48^s{\cdot}6$ *additive*; hour-angle $3^h\ 51^m\ 25^s$; mean time ship $16^d\ 27^h\ 57^m\ 14^s$. *Longitude* 89° 41' 15" E.
10. Green. date $4^d\ 1^h\ 53^m\ 22^s$; red decl. 22° 51' 51" N.; true alt. 12° 21' 31"; sum of logs. 19·206642; true azimuth N. 47° 18' 6" E. *Variation* 17° 18' 6" E.
11. Time from noon $25^m\ 20^s$; Green. date $30^d\ 18^h\ 52^m\ 32^s$; red. decl. 18° 16' 23" N.; true alt. 26° 24' 19"; mer. zen. dist. 63° 19' 57" S. *Latitude* 45° 3' 34" S.

Towson: Aug. I, + 6' 16"; index 63; aug. II, + 9' 27". *Latitude* 45° 3' 35" S.

12. Star's decl. 26° 7' 47" S.; true alt. 70° 5' 46". *Latitude* 46° 2' 1" S.
13. N. 2° 59' E.; N. 7° 24' W.

EXAMINATION PAPER—No. VIII, *Pages* 200—202.

1. 5·889986 = 776221 +.
2. 2·676541 = 474·83.
3. TRUE COURSES.—N. $4\frac{3}{4}$ E., 15; S. $2\frac{1}{4}$ E., 26; N. $3\frac{3}{4}$ W., 27·1; N. $4\frac{3}{4}$ W., 22; S. $2\frac{1}{2}$ E., 25; S. 3 E., 22; N. $6\frac{1}{4}$ W., 43; S. $1\frac{3}{4}$ W., 18. *Diff. lat.* 24·3; *dep.* 35·4; *course* S. 56° W.; *dist.* 35·4'. *Lat. in* 0° 14' S.; *diff. long.* 35 W. *Long. in* 173° 15' E.
4. Green. date $11^d\ 17^h\ 51^m\ 12^s$; red. decl. 14° 59' 12" N.; true alt. 42° 50' 17". *Latitude* 32° 10' 31" S.
5. Log. of diff. long. 2·805956 = *Diff. long.* 639·6 +.
6. Diff. lat. 421' N.; mer. diff. lat. 590; diff. long. 249' E.; *course* N. 22° 52' 53" E.; *distance* 457, nearly.
7. $7^h\ 12^m$ A.M., $7^h\ 54^m$ P.M. $6^h\ 34^m$ A.M., $7^h\ 16^m$ P.M.

7*a*. No A.M., $0^h\ 19^m$ P.M. $10^h\ 35^m$ A.M., $11^h\ 13^m$ P.M. (Method II.)

7*b*. Correction + 8^m, $1^h\ 3^m$ A.M., $1^h\ 26^m$ P.M. (Method III.)

8. Green. date July $31^d\ 23^h\ 53^m\ 44^s$; red. decl. 17° 58' 17" N.; true amp. W. 22° 44' 33" N. *Variation* 2° 34' 12" W.
9. Green. date $6^d\ 20^h\ 32^m\ 37^s$; red. decl. 16° 24' 31" N.; true alt. 24° 17' 1"; red. eq. time $5^h\ 30^m$ *additive*; hour-angle $4^h\ 25^m\ 44^s$; mean time ship $6^d\ 28^h\ 31^m\ 14^s$. *Longitude* 119° 39' 15" E.

10. Green. date Aug. $19^d 20^h 37^m 39^s$; red. decl. $12° 25' 19''$ N.; true alt. $17° 36' 21''$; sum of logs. 19·054055; true azimuth N. $39° 19' 54''$ W. *Variation* $33° 42' 24''$ W.

11. Time from noon $35^m 15^s$; Green. date $10^d 12^h 55^m 5^s$; red. decl. $15° 20' 47''$ N; true alt. $34° 48' 15''$; nat. cos. mer. zen. dist. $54° 34' 36''$ S. *Latitude* $39° 13' 49''$ S.
Towson: Aug. I + $10' 30''$; index 90; aug. II + $26' 38''$. *Latitude* $39° 13' 50''$ S.

12. Star's decl. $8° 31' 14''$ N.; true alt. $66° 48' 17''$. *Latitude* $14° 40' 29''$ S.

13. S. $70° 41'$ W.; N. $72° 24'$ W.

EXAMINATION PAPER—No. IX, *Pages* 202—203.

1. 5·060365 = 114912. (The product.)
2. 2·513218 = 326·0. (The quotient.)
3. True Courses.—S. $5\frac{1}{4}$ W., 14; S. $2\frac{1}{4}$ W., 19·6; W., 22; S. 1 E., 13·2; N. $3\frac{1}{4}$ W., 7; S. $\frac{1}{2}$ W., 8·4; N. $3\frac{1}{2}$ W., 4·5; S. 3 W., 13·8; N. $2\frac{1}{4}$ W., 5·6; S. 5 W., 9; N. $\frac{1}{4}$ W., 32. *Diff. lat.* 16·8; *dep.* 67·1; *course* S. 76° W.; *dist.* 69'. *Lat. in* $57° 40'$ N.; *diff. long.* 127. *Long. in* $5° 5'$ E.
4. Green. date $22^d 8^h 15^m 0^s$; red. decl. $0° 4' 44''$ N.; true alt. $90° 1' 49''$. *Latitude* $0° 6' 33''$ N.
5. Log. of diff. long. 2·574252 = *Diff. long.* 375·2.
6. Diff. lat. 3607' S.; mer. diff. lat. 3798'; diff. long. 4007' E.; *course* S. $46° 32' 2''$ E.; *distance* 5243'.
7. $0^h 17^m$ A.M., $0^h 58^m$ P.M. $11^h 49^m$ A.M., no P.M. $11^h 53^m$ A.M., no P.M. Noon. No A.M., $0^h 2^m$ P.M.

7*a*. $5^h 0^m$ A.M., $5^h 23^m$ P.M. $6^h 3^m$ A.M., $6^h 26^m$ P.M. (Method II.)

7*b*. Semid. $15' 24''$; corr. — 3^m; $0^h 13^m$ A.M., $0^h 40^m$ P.M. (Method III.)

8. Green. date $18^d 20^h 29^m 32^s$; red. decl. $1° 26' 16''$; true amp. E. $1° 46' 6''$ N. *Variation* $1° 46' 6''$ W.
9. Green. date August $31^d 15^h 35^m 10^s$; red. decl. $8° 19' 20''$ N.; red. eq. time $0^m 5^s$ *subtractive*; true alt. $62° 25' 6''$; hour-angle $1^h 51^m 36^s$ *subtractive*; mean time ship August $31^d 25^h 51^m 31^s$. *Longitude* $154° 5' 15''$ E.
10. Green. date $16^d 1^h 29^m 54^s$; red. decl. $2° 31' 7''$ N.; true alt. $29° 42' 0''$; sum of logs. 19·702079; true azimuth S. $90° 24' 42''$ E. *Variation* $8° 15' 18''$ E.
11. Time from noon $16^m 57^s$; Green. date $22^d 12^h 27^m 39^s$; red. decl. $0° 0' 38''$ S.; true alt. $62° 9' 19''$; mer. zen. dist. $27° 32' 45''$ S. *Latitude* $27° 32' 7''$ S.
Towson: Aug. I, + 0; index 36; aug. II, + $18' 7''$. *Latitude* $27° 31' 56''$ S.
12. Star's decl. $19° 53' 13''$ N.; true alt. $86° 31' 21''$. *Latitude* $16° 24' 31''$ N.
13. N. $1° 14'$ E.; S. $66° 13'$ E.

EXAMINATION PAPER—No. X, *Pages* 203—205.

1. 3·283783 = 1922·13 +.
2. 2·936010 = 86·30.
3. True Courses.—N. $5\frac{3}{4}$ E., 16; S. $\frac{1}{4}$ W., 17; S. $2\frac{3}{4}$ W., 19; N. $4\frac{1}{4}$ E., 17; N. $6\frac{1}{2}$ E., 9; S., 3; S. $4\frac{3}{4}$ W., 3; S. 4 E., 13; N. $7\frac{3}{4}$ E., 21. *Diff. lat.* 25·5 S; *dep.* 52·9 E.; *course* S. 64° E.; *dist.* 59'. *Lat. in* $59° 23'$ N.; *diff. long.* 106'. *Long. in* $42° 8'$ W.

4. Green. date $20^d\ 10^h\ 1^m\ 40^s$; red. decl. $10^\circ 35' 59''$ S.; true alt. $50^\circ 11' 14''$. *Latitude* $50^\circ 24' 45''$ S.

5. Log. of diff. long. 2·380711 = *Diff. long.* 240·2.

6. Diff. lat. 140′ N.; mer. diff. lat. 142′; diff. long. 214′ E.; *course* N. $56^\circ 26' 19''$ E.; *distance* 253′·2.

7. $11^h\ 22^m$ A.M., no P.M. $8^h\ 40^m$ A.M., $9^h\ 21^m$ P.M. $6^h\ 33^m$ A.M., $7^h\ 14^m$ P.M. $4^h\ 59^m$ A.M., $5^h\ 40^m$ P.M.

7*a*. $10^h\ 40^m$ A.M., $11^h\ 14^m$ P.M. (Method II.)

7*b*. $0^h\ 17^m$ P.M. no A.M. (Method III.)

8. Green. date $8^d\ 11^h\ 13^m\ 48^s$; red. decl. $6^\circ 10' 15''$ S.; true amp. E. $6^\circ 31' 5''$ S. *Variation* $1^\circ 55' 10''$ W.

9. Interval $105^d\ 4^h$; Green. date $30^d\ 3^h\ 45^m\ 57^s$; red. decl. $13^\circ 56' 39''$ S.; true alt. $28^\circ 56' 36''$; hour-angle $4^h\ 11^m\ 49^s$; red. eq. time $16^m\ 13^s$ 8 *subt.* from app. time; mean time at ship $29^d\ 19^h\ 31^m\ 57^s$. *Longitude* $123^\circ 30' 0''$ W.

10. Green. date Sept. $30^d\ 18^h\ 43^m\ 48^s$; red. decl. $3^\circ 12' 45''$ S.; true alt. $14^\circ 7' 3''$; sum of logs. 19·691494; true az. N. $89^\circ 1' 20''$ W. *Variation* $9^\circ 24' 55''$ E.

11. Time from noon $17^m\ 8^s$; Green. date $2^d\ 1^h\ 17^m\ 8^s$; red. decl. $3^\circ 42' 13''$ S.; true alt. $47^\circ 39' 40''$; mer. zen. dist. $42^\circ 9' 8''$ N. *Latitude* $38^\circ 26' 55''$ N.

Towson: Aug. I + 37″; index 36; aug. II + 10′ 28″. *Latitude* $38^\circ 27' 2''$ N.

12. Star's decl. $14^\circ 29' 17''$ N.; true alt. $54^\circ 6' 7''$. *Latitude* $50^\circ 23' 10''$ N.

13. N. $62^\circ 21'$ W.; N. $16^\circ 13'$ E.; N. $9^\circ 54'$ W.; N. $58^\circ 42'$ E.

EXAMINATION PAPER—No. XI, *Pages* 205—206.

1. 4·820656 = 66169·2. (The product.)

2. 0·948890 = 8·889+. (The quotient.)

3. True Courses.—S. $3\frac{1}{2}$ W., 16; N. 1 E., 17; S. $5\frac{1}{2}$ E., 19·4; N. $6\frac{3}{4}$ W., 31·1; S. $6\frac{3}{4}$ E., 17·4; S. $1\frac{1}{4}$ E., 19; S. $6\frac{1}{2}$ W., 24·9; S. $7\frac{3}{4}$ E., 22·5. *Diff. lat.* 29·3 S.; *dep.* 0·7 E.; *course* S. 2° E.; *dist.* 30′. *Lat. in* $51^\circ 31'$ N.; *diff. long.* 1′ E. *Long. in* $120^\circ 1'$ E.

4. Green. date $14^d\ 18^h\ 39^m\ 16^s$; red. decl. $18^\circ 31' 11''$ S.; true alt. $67^\circ 57' 49''$. *Latitude* $40^\circ 33' 22'$ S.

5. Log. of diff. long. 2·294311 = *Diff. long.* 196·9+.

6. Diff. lat. 1928′ N.; mer. diff. lat. 2383′; diff. long. 4290′ E.; *course* N. $60^\circ 56' 56''$ E.; *distance* 3970′·4+.

7. $11^h\ 47^m$ A.M., no P.M. tide. No A.M., $0^h\ 12^m$ P.M. $11^h\ 53^m$ A.M., no P.M.

7*a*. $11^h\ 45^m$ A.M., no P.M. (Method II.)

7*b*. $6^h\ 4^m$ A.M., $6^h\ 32^m$ P.M. (Method III.)

8. Green. date $9^d\ 12^h\ 20^m\ 44^s$; red. decl. $17^\circ 6' 14''$ S.; true amp. E. $33^\circ 56' 39''$ S. *Variation* $36^\circ 22' 6''$ W.

9. Interval $36^d\ 3^h$; Green. date $30^d\ 2^h\ 48^m\ 52^s$; red. decl. $21^\circ 43' 51''$ S.; red. eq. time $11^m\ 0^s$ *subtractive*; true alt. $39^\circ 47' 7''$; hour-angle $3^h\ 42^m\ 11^s$; mean time ship $29^d\ 20^h\ 6^m\ 49^s$. *Longitude* $100^\circ 30' 45''$ W.

10. Green. date $15^d\ 10^h\ 46^m\ 27^s$; red. decl. $18^\circ 41' 32''$ S.; true alt. $43^\circ 55' 7''$; true azimuth N. $69^\circ 47' 4''$ W., or S. $110^\circ 12' 56''$ W. *Variation* $16^\circ 42' 56''$ E.

11. Time from noon $39^m\ 26^s$; Green. date $13^d\ 2^h\ 36^m\ 2^s$; red. decl. $18^\circ 5' 11''$ S.; true alt. $56^\circ 11' 51''$; mer. zen. dist. $32^\circ 52' 45''$ S. *Latitude* $50^\circ 57' 56''$ S.

12. Star's decl. $30^\circ 19' 57''$ S.; true alt. $59^\circ 36' 2''$. *Latitude* $60^\circ 43' 55''$ S.

13. S. $43^\circ 49'$ E.; S. $46^\circ 7'$ W.; N. $68^\circ 25'$ E.

EXAMINATION PAPER—No. XII, *Pages* 206—208.

1. 2·573829 = 374·825.
2. 3·168317 = 1473·38 +.
3. True Courses.—S. 3 W., 16; N. $5\frac{1}{2}$ E., 13·1; S. $5\frac{1}{4}$ W., 15; S. $3\frac{1}{2}$ E., 15·1; N. $3\frac{3}{4}$ W., 15·5; N. $6\frac{1}{2}$ E., 15·6; S. $5\frac{1}{4}$ W., 16; S. $1\frac{1}{2}$ E., 6. *Diff. lat.* 24·5 S; *dep.* 8·3 W.; *course* S. 19° W.; *dist.* 26'. *Lat. in* 46° 46'·5 N.; *diff. long.* 12'. *Long. in* 3° 24' W.
4. Green. date 31^d 8^h 15^m; red. decl. 23° 3' 24" S.; true alt. 67° 20' 49". *Latitude* 0° 24' 13" S.
5. Log. of diff. long. 2·346353 = *Diff. long* 222'.
6. Diff. lat. 4766' S.; mer. diff. lat. 5205'; diff. long. 3735' W.; *course* S. 35° 39' 45" W. *distance* 5866'.
7. 10^h 45^m A.M., 11^h 8^m P.M. Noon. 0^h 4^m A.M., 0^h 30^m P.M. No A.M., 0^h 23^m P.M.

7*a*. 11^h 13^m A.M., 11^h 34^m P.M. (Method II.)

7*b*. No A.M., 0^h 11^m P.M. (Method III.)

8. Green. date 28^d 4^h 10^m 49^s; red. decl. 23° 16' 2" S.; true amp. E. 35° 13' 52" S. *Variation* 15° 32' 37" E.
9. Green. date 24^d 8^h 13^m $24^s{\cdot}5$; red. decl. 23° 24' 59" S.; red. eq. time *add* 0^m $8^s{\cdot}4$; true alt. 40° 54' 8"; hour-angle 3^h 43^m 17^s. *Longitude* 178° 38' 15" W.
10. Green. date 27^d 4^h 40^m 10^s; red. decl. 23° 18' 59" S.; true alt. 20° 27' 7"; true azimuth S. 57° 22' 46" E. *Variation* 6° 18' 29" E.
11. Time from noon 30^m 40^s; Green. date 4^d 1^h 30^m 0^s; red. decl. 22° 18' 16" S.; true alt. 60° 7' 18"; zen. dist. 29° 17' 10' S. *Latitude* 51° 35' 26" S.
12. Star's decl. 5° 33' 48" N.; true alt. 52° 45' 55". *Latitude* 31° 40' 17" S.
13. S. 88° 20' E.; S. 38° 44' W.; N. 14° 25' W.; N. 80° 58' E.

EXAMINATION PAPER—No. XIII, *Pages* 208—209.

1. 3·760573 = 5762.
2. 1·909591 = 81·2066.
3. True Courses.—N. $7\frac{1}{2}$ W., 18; N. $7\frac{1}{4}$ W., 10·4; N. $5\frac{1}{4}$ W., 9·9; N. $2\frac{3}{4}$ W., 9·9; S. 4 W., 14; N. $\frac{1}{4}$ W., 15·9; N. $5\frac{3}{4}$ W., 7·3; S. $1\frac{3}{4}$ E., 7·6; N. $7\frac{1}{4}$ W. 8·6; N. 7 W., 6·1; S. $5\frac{3}{4}$ E., 16. *Diff. lat.* 13·6 N.; *dep.* 56·6 W.; *course* N. $76\frac{1}{2}$° W.; *distance* 58'. *Lat. in* 36° 21' S.; *diff. long.* 70'. *Long. in* 111° $35\frac{1}{2}$' W.
4. Green. date 10^d 17^h 51^m 12^s; red. decl. 15° 17' 8" N.; true alt. 42° 50' 17". *Latitude* 31° 52' 35" S.
5. Log. of diff. long. 2·149455 = *Diff. long.* 141'·08.
6. Diff. lat. 1890' S.; mer. diff. lat. 2392'; diff. long. 1894' W.; *course* S. 38° 22' 21" W. *distance* 2411'.
7. 3^h 1^m A.M., 3^h 32^m P.M. 10^h 13^m A.M., 10^h 41^m P.M. No A.M., 0^h 13^m P.M.

7*a*. 6^h 52^m A.M., 7^h 18^m P.M. (Method II.)

7*b*. 4^h 14^m A.M., 4^h 37^m P.M. (Method III.)

8. Green. date 28^d 4^h 14^m 48^s; red. decl. 13° 17' 12" S.; true amp. E. 20° 47' 55" S. *Variation* 24° 7' 55" E.
9. Green. date 10^d 5^h 22^m 13^s; red. decl. 8° 8' 31" N.; true alt. 44° 44' 11"; red. eq. time 1^m $13^s{\cdot}4$ *additive*; hour-angle 2^h 37^m 41^s. *Longitude* 40° 49' 45" W.
10. Green. date 8^d 16^h 22^m 6^s; red. decl. 4° 29' 32" S.; true alt. 28° 33' 55"; sum of logs. 19·596069; true azimuth S. 102° 10' 44" E. *Variation* 21° 50' 44" W.

11. Time from noon $25^m\ 52^s$; Green. date $28^d\ 2^h\ 10^m\ 8^s$; red. decl. 18° 55′ 16″ N.; true alt. 69° 22′ 20″; mer. zen. dist. 19° 51′ 8″ N. *Latitude* 38° 46′ 24″ N.

12. Star's decl. 47° 36′ 31″ S.; true alt. 49° 54′ 3″. *Latitude* 7° 30′ 34″ S.

13. N. 14° 25′ W.; S. 89° 35′ E.; S. 43° 39′ W.

EXAMINATION PAPER—No. XIV, *Pages* 209—211.

1. 3·284431 = 1925.

2. 1·469705 = 29·4920.

3. True Courses.—S. 4 E., 21; S. 6¼ E., 14·1; S. 1 E., 6·7; N. 3¼ W., 5; N. 1½ E., 18·2; S. 1½ W., 16·7; S. 6¾ W., 22·4; N. 4¼ W., 15·3; N., 4·4; S. 1¾ W., 10·9; N. 4½ E., 14. *Diff. lat.* 12·9 S.; *dep.* 0·9 E.; *course* S. 4° E.; *dist.* 13′. *Lat. in* 34° 41′ S.; *diff. long.* 1·5 E. *Long. in* 18° 29′·5 E.

4. Green. date $10^d\ 21^h\ 50^m\ 40^s$; red. decl. 13° 56′ 13″ S.; true alt. 30° 33′ 20″. *Latitude* 45° 30′ 27″ N.

5. Log. of diff. long. 2·010904 = *Diff. long.* 102·542.

6. Diff. lat. 4202′ N.; mer. diff. lat. 4555′; diff. long. 4847′ E.; *course* N. 46° 46′ 44″ E.; *distance* 6136′.

7. $11^h\ 3^m$ A.M., $11^h\ 31^m$ P.M. $11^h\ 30^m$ A.M., $11^h\ 58^m$ P.M. $11^h\ 20^m$ A.M., $11^h\ 48^m$ P.M.

7*a*. $8^h\ 7^m$ A.M., $8^h\ 30^m$ P.M. (Method II.)

7*b*. $8^h\ 56^m$ A.M., $9^h\ 17^m$ P.M. (Method III.)

8. Green. date $30^d\ 7^h\ 41^m\ 8^s$; red. decl. 4° 0′ 48″ N.; true amp. E. 4° 2′ 22″ N. *Variation* 7° 53′ 22″ W.

9. Green. date $26^d\ 21^h\ 9^m\ 33^s$; red. decl. 21° 19′ 41″ N.; red. eq. time $3^m\ 8^s\!\cdot\!3$ *subt.*; true alt. 43° 20′ 9″; hour-angle $2^h\ 53^m\ 31^s$. *Longitude* 1° 33′ 0″ W.

10. Green. date $10^d\ 0^h\ 59^m\ 46^s$; red. decl. 4° 49′ 42″ N.; true alt. 27° 35′ 57″; sum of logs. 19·499122; true azimuth N. 68° 21′ 26″ E. *Variation* 12° 4′ 26″ E.

11. Time from noon $30^m\ 41^s$; Green. date $7^d\ 18^h\ 31^m\ 53^s$; red. decl. 16° 36′ 18″ S.; true alt. 40° 4′ 46″; mer. zen. dist. 49° 22′ 53″ N. *Latitude* 32° 46′ 35″ N.

Towson: Aug. I, + 8′ 33″; index 81; aug. II, + 24′ 12″. *Latitude* 32° 46′ 11″ N.

12. Star's decl. 57° 9′ 30″ S.; true alt. 32° 48′ 59″. *Latitude* 0° 1′ 31″ N.

EXAMINATION PAPER—No. XV, *Pages* 211—212.

1. 3·511573 = 3247·68.

2. 1·243292 = 17·5102.

3. True Courses.—N. 6 E., 15; S. 6½ E., 13·6; S. 6 E., 9·8; S. 2½ E., 16·5; N. 3¾ E., 22; N. 6¼ E., 7·8; S. 7¾ E., 8·4; S. 7¼ E., 13·8; N. ½ W., 18·5; N. 7¼ E. 14·3; N. 5 W., 22·2; N. 7¾ E., 31·2. *Diff. lat.* 34·1 N.; *dep.* 113·1 E.; *course* N. 73° E.; *dist.* 117. *Lat. in* 35° 46′ S.; *diff. long.* 140′ E. *Long. in* 54° 25′ W.

4. Green. date $20^d\ 19^h\ 18^m\ 40^s$; red. decl. 19° 57′ 17″ S.; true alt. 80° 28′ 59″. *Latitude* 29° 28′ 18″ S.

5. Log. of diff. long. 1·909671 = *Diff. long.* 81·2215.

6. Diff. lat. 731′ S.; mer. diff. lat. 733′; diff. long. 1259′ E.; *course* S. 59° 47′ 30″ W.; *distance* 1453′.

7. No A.M., $0^h\ 8^m$ P.M. $0^h\ 5^m$ A.M., $0^h\ 32^m$ P.M. No A.M., $0^h\ 24^m$ P.M.

7*a*. $6^h\ 4^m$ A.M., $7^h\ 3^m$ P.M. (Method II.)

7*b*. No A.M., $0^h\ 3^m$ P.M. (Method III.)

8. Green. date $16^d\ 8^h\ 2^m\ 24^s$; red. decl. 20° 48′ 33″ S.; true amp. W. 29° 5′ 47″ S. *Variation* 23° 9′ 47″ W.

9. Green. date $4^d\ 12^h\ 33^m\ 40^s$; red. decl. 22° 31′ 52″ N.; true alt. 28° 18′ 52″; red. eq. time *subt.* $1^m\ 54^s$; hour-angle $3^h\ 52^m\ 16^s$. *Longitude* 113° 2′ 30″ E.

10. Green. date $9^d\ 14^h\ 58^m\ 46^s$; red. decl. 17° 8′ 17″ S.; true alt. 6° 11′ 26″; sum of logs. 19·303669; true azimuth S. 53° 18′ 16″ E. *Variation* 7° 11′ 44″ E.

11. Time from noon $9^m\ 5^s$; Green. date $8^d\ 3^h\ 31^m\ 43^s$; red. decl. 22° 10′ 51″ S.; true alt. 76° 57′ 49″; mer. zen. dist. 12° 53′ 4″ S. *Latitude* 35° 3′ 55″ S.

12. Star's decl. 16° 32′ 18″ S.; true alt. 37° 45′ 59″. *Latitude* 35° 41′ 43″ N.

13. S. 46° 22′ E.; S. 41° 12′ W.

EXAMINATION PAPER—No. XVI, *Pages* 212—214.

1. Log. of product 6·447933 = product 2805000.

2. Log. of quotient 4·986680 = quotient 96979·5+.

3. True Courses.—N. $5\frac{1}{4}$ W., 15; N. $4\frac{1}{4}$ W., 8·6; N. $4\frac{1}{2}$ W., 14·2; N. $5\frac{3}{4}$ W., 6·5; N. $5\frac{1}{2}$ W., 11; S. $6\frac{1}{4}$ W., 15·9; N. $4\frac{3}{4}$ E., 8; N. 6 W., 7·3; N. $6\frac{3}{4}$ W., 6·4; N. $2\frac{1}{2}$ W., 6·4; N. 4 E., 2·8; S. $3\frac{1}{4}$ W., 2·4; N. $1\frac{3}{4}$ W., 3·3; S. $3\frac{3}{4}$ W., 6·8; N. $\frac{1}{2}$ E., 12·5; S. $6\frac{3}{4}$ W., 6·7; N., 6·4; N. 5 W., 5; N. $5\frac{3}{4}$ W., 5·3; S. $4\frac{1}{2}$ W., 19. *Diff. lat.* 48·4 N.; *dep.* 104·5 W.; *course* N. 65° W.; *dist.* 115′. *Lat. in* 55° 38·6′ S.; *diff. long.* 187 W. *Long. in* 71° 44′ W.

4. Green. date 1865, December $31^d\ 12^h\ 48^m\ 24^s$; red. decl. 23° 2′ 30″ S.; true alt. 83° 52′ 24″. *Latitude* 16° 54′ 54″ S.

5. Diff. long. 192·4 W. *Long. in* 182° 29′ W., or 177° 31′ E.

6. Diff. lat. 2747′ S.; mer. diff. lat. 2919; diff. long. 6340′ W.; *course* S. 65° 16′ 42″ W.; *distance* 6569′.

7. $9^h\ 17^m$ A.M., $9^h\ 3^m$ P.M. $4^h\ 31^m$ A.M., $4^h\ 53^m$ P.M.

7*a*. $6^h\ 52^m$ A.M., $7^h\ 23^m$ P.M. (Method II.)

7*b*. $8^h\ 23^m$ A.M., $9^h\ 1^m$ P.M. (Method III.)

8. Green. date November $3^d\ 17^h\ 28^m\ 30^s$; red. decl. 15° 23′ 35″ S.; true amp. E. 22° 45′ 20″ S. *Variation* 16° 37′ 10″ W.

9. Green. date August $31^d\ 19^h\ 54^m\ 30^s$; red. decl. 8° 15′ 26″ N.; eq. time — $0^m\ 8^s$; true alt. 15° 25′ 43″; hour-angle $4^h\ 45^m\ 31^s$. *Longitude* 10° 2′ 15″ W.

10. Green. date May $31^d\ 16^h\ 13^m$; red. decl. 22° 3′ 15″ N.; true alt. 39° 20′ 26″; true azimuth S. 101° 43′ 42″ E. *Variation* 3° 17′ 27″ W.

11. Green. date April $12^d\ 14^h\ 1^m\ 5^s$; time from noon $10^m\ 15^s$; red. decl. 9° 0′ 17″ N.; true alt. 80° 43′ 11″; nat. no. 988. *Latitude* 0° 4′ 56″ N.

12. Star's decl. 60° 16′ 34″ S.; true alt. 9° 52′ 32″. *Latitude* 19° 50′ 54″ N.

EXAMINATION PAPER—No. XVII, *Pages* 214—215.

1. Log. of product 3·955448 = product 9025·0.

2. Log. of quotient 3·954292 = quotient 9001·0.

3. True Courses.—S. $6\frac{1}{2}$ E., 23; N. $\frac{1}{4}$ W., 12·2; N. $\frac{3}{4}$ W., 15·9; S. 6 E., 6; S. $5\frac{1}{4}$ E., 3; S. $3\frac{1}{2}$ E., 3; S. $4\frac{1}{4}$ W., 4·5; S. $7\frac{3}{4}$ W., 3; S. $3\frac{1}{2}$ W., 3; N. $7\frac{1}{2}$ W., 37·8; N. $6\frac{1}{2}$ W., 10. *Diff. lat.* 16·3 N.; *dep.* 26·3 W.; *course* N. 58° W.; *dist.* 31′. *Lat. in* 34° 12′ S.; *diff. long.* 32′ W. *Long. in* 17° 56′ E.

4. Green. date $22^d\ 20^h\ 9^m$; red. decl. 0° 6′ 52″ S.; true alt. 84° 21′ 18″. *Latitude* 5° 45′ 34″ S.

5. Diff. long. 220·9 E., or 3° 41′ E. *Long. in* 3° 1′ E.
6. Diff. lat. 2531′ S.; mer. diff. lat. 2701; diff. long, 7433′ E.; *course* S. 70° 1′ 47″ E.; *distance* 7411′.
7. $11^h 26^m$ A.M., $11^h 54^m$ P.M. $2^h 28^m$ A.M., $2^h 56^m$ P.M. $4^h 54^m$ A.M., $5^h 22^m$ P.M.
7*a*. $0^h 55^m$ A.M., $1^h 17^m$ P.M. $2^h 35^m$ A.M., $2^h 57^m$ P.M.
7*b*. Correction + 10^m, $7^h 55^m$ A.M., $8^h 25^m$ P.M.
8. Green. date Nov. $4^d 21^h 23^m$; red. decl. 15° 44′ 57″ S.; true amp. W. 16° 52′ 24″ S. *Variation* 19° 41′ 21″ E.
9. Green. date Aug. $5^d 8^h 8^m 45^s$; red. decl. 16° 49′ 41″ N.; red. eq. time + $5^m 41^s$; true alt. 35° 16′ 45″; hour-angle $3^h 54^m 6^s$. *Longitude at sight* 179° 17′ 30″ W.; *diff. long. since* 55° 42′. *Longitude at noon* 180° 13′ 12″ W., or 179° 46′ 48″ E.
10. Green. date Aug. $13^d 2^h 20^m 40^s$; red. decl. 14° 34′ 38″ N.; true alt. 27° 27′ 29″; true azimuth N. 50° 19′ 48″ E. *Variation* 15° 19′ 48″ E.
11. Green. date June 11^d $19^h 42^m 30^s$; time from noon $31^m 18^s$; red. decl. 23° 10′ 2″ N.; true alt. 50° 14′ 43″; nat. no. 8235. *Latitude* 15° 50′ 37″ S.
12. Star's decl. 22° 49′ 41″ N.; true alt. 60° 23′ 4″. *Latitude* 52° 26′ 37″ N.

EXERCISES ON THE CHART.

FOR ONLY AND FIRST MATES.

North Sea, Page 225.

1.	Course W. ¼ S.	Dist. 49′	2.	Course S. by W.	Dist. 34′
3.	„ S.W. ¼ W.	„ 163	4.	„ N. ½ E.	„ 35
5.	„ S. by W. ¾ W.	„ 19	6.	„ W. by S. ¼ S.	„ 41
7.	„ S.W. ¼ S.	„ 67	8.	„ S.W. by W. (nrly)	„ 75
9.	„ S.E. ¼ S.	„ 149	10.	„ S.E. by S.	„ 50

English and Bristol Channels and South Coast of Ireland, Page 226.

1.	Course S.W. by W.	Dist. 21′	2.	Course S.E. by E.	Dist. 43′
3.	„ N. by E. ½ E.	„ 44½	4.	„ S.S.E. ½ E.	„ 37
5.	„ S.E. ½ E.	„ 34	6.	„ N. by W. (nrly.)	„ 30
7.	„ N.N.E. ½ E.	„ 25½	8.	„ N.E. ¾ E. „	„ 72½
9.	„ E. by N. ¼ N.	„ 36	10.	„ N. by W. ¼ W.	„ 16
11.	„ E. by N. ¼ N.	„ 50	12.	„ S.E. ¼ E.	„ 77
13.	„ N. by W. ¾ W.	„ 65	14.	„ N. ¾ W.	„ 67
15.	„ E. ¼ S.	„ 76	16.	„ E. ⅛ S.	„ 35½

ORDINARY MASTER.

North Sea, Pages 226—227.

1.	Lat. 55° 15½′ N.	Long. 1° 11′ W.	Course S.S.W.	Distance 34′
2.	„ 57 16 N.	„ 1 28 W.	„ S.S.W. ¼ W.	„ 96
3.	„ 60 4 N.	„ 0 24 W.	„ S.W. ½ S. (nearly)	„ 159
4.	„ 53 20 N.	„ 1 36 E.	„ N.N.W. ¾ W.	„ 75½

XX

English and Bristol Channels and South Coast of Ireland, Page 227.

1.	Lat. 49° 48′ N	Long. 6° $7\frac{1}{2}$′ W.	Course E. by S.	Distance 37′
2.	„ 49 40 N.	„ 1 3 W.	„ S.E. $\frac{3}{4}$ E.	„ 45
3.	„ 50 35 N.	„ 0 55 W.	„ N.W. by W. $\frac{3}{4}$ W.	„ 15
4.	„ 50 32 N.	„ 1 $30\frac{1}{2}$ W.	„ N.W. by W.	„ 21
5.	„ 51 25 N.	„ 4 59 W.	„ N.N.W. $\frac{1}{2}$ W.	„ 32
6.	„ 49 $51\frac{1}{2}$ N.	„ 5 35 W.	„ N.W. by W. $\frac{1}{2}$ W.	„ 30
7.	„ 51 47 N.	„ 7 $42\frac{1}{2}$ W.	„ W. by N.	„ $32\frac{1}{2}$

SOUNDINGS.

Half-range, *Page* 231.

1. 9 feet 3 inches. 2. 9 feet 8 inches. 3. 22 feet 0 inches.

Depths, &c., *Page* 232.

1. Time from high water $1^h\ 31^m$; half-range for day 18 feet 5 inches; table B + 12 feet 11 inches. Depth of water required 55 feet 6 inches, or $9\frac{1}{4}$ fathoms.

2. Time from high water $1^h\ 48^m$; half-range for day 10 feet 5 inches; table B + 6 feet 1 inch. Depth at Fairway Buoy 34 feet 7 inches, or $5\frac{3}{4}$ fathoms.

3. Time *before* high water $3^h\ 10^m$; half-range for day 12 feet 7 inches; table B — 1 foot 1 inch. Depth 24 feet 11 inches.

4. Time *before* high water $0^h\ 19^m$; correction to low water 43 feet 6 inches. The ship found 4 feet 6 inches dry.

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